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FUELS FOR RAILWAY AND MARINE DIESELS

Prepared for the

TRANSPORTATION DEVELOPMENT CENTRE

Prepared by

Hycarb Engineering Ltd.

December, 1983

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FUELS FOR RAILWAY AND MARINE DIESELS

by

Hycarb Engineering Ltd.

T. H. Wise
G. R. Crandall
J. N. Zanyk

December, 1983

The contents of this report reflect the views of the contractor and not necessarily the official views or policies of the Transport Canada, Transportation Development Centre.

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17. Abstract

An investigation was undertaken to determine the future availability and quality of fuels for railway and marine diesels. In this regard, a forecast of petroleum product demand and crude oil availability up to 1995 was established. The petroleum refining industry was then analyzed as to its ability to adjust operations to meet the future demands. As an aid in the refinery analysis, a linear programming model was utilized to simulate the refining industry on a regional basis. Conclusions with respect to the future supply situation were drawn. Future fuel prices were estimated. Considerations were identified to match engine fuel requirements with fuel quality, to improve fuel quality control, and to reduce fuel costs.

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17. Résumé

Une enquête a été entreprise afin d'évaluer la disponibilité future et la qualité du combustible diesel pour locomotives et navires. A cet effet, on a établi une prévision de la demande de produits pétroliers et de la disponibilité d'huile brute jusqu'en 1995. L'industrie de raffinage du pétrole a subi une analyse permettant d'évaluer sa capacité d'ajuster ses opérations pour répondre aux demandes futures. Afin de faciliter cette analyse, on a utilisé un modèle de programmation linéaire qui représente l'industrie de raffinage sur une base régionale. Ensuite, on a tiré des conclusions sur la situation d'approvisionnements futurs et estimé les prix futurs en carburant diesel. On a identifié les considérations pour mettre en correspondance la demande des moteurs en carburant avec la qualité de ce dernier, améliorer le contrôle de la qualité et réduire le coût de carburant.

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Mr. R. Bertrand	Transportation Development Centre
Mr. D. S. Black	Energy, Mines and Resources
Mr. P. J. Detmold	Railway Advisory Committee
Mr. I. F. Gilbert	Transport Canada
Mr. R. G. Grimsey	National Defence
Mr. D. R. Jackson	CN Rail
Mr. R. G. Maughan	Transportation Development Centre (Consultant)
Mr. D. O. Mullins	CP Rail
Mr. R. S. Nishizaki	Transportation Development Centre
Mr. G. Taylor	Energy, Mines and Resources
Mr. R. B. Whyte	National Research Council
Mr. D. Williams	CN Marine

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1. INTRODUCTION

The Transportation Development Centre (TDC) of Transport Canada is concerned with availability and quality of fuels for transportation use to ensure that refinery products and engine requirements are compatible and cost effective in the future. In 1980, Hycarb Engineering Ltd. (Hycarb) completed a study for TDC on the availability and quality of diesel fuel for railways during the 1980's. In that study, short-term supply shortages were forecast for the Prairie region (and did occur because of insufficient refining capacity); in the long-term, diesel quality problems were forecast in most regions of Canada because of a high proportion of synthetic crude oil which was expected to be available.

Circumstances have changed since that study was completed. New refining capacity has been coming onstream in western Canada. Total product demand and crude running has fallen sharply across Canada, and many refineries across Canada, particularly in the east, are being shut down. Slower development of Canada's oil sands is now expected, resulting in less synthetic crude production than previously forecast. Depending on frontier (offshore) crude developments, this could lead to continuing dependence on foreign sources of crude oil supply.

Because of substantial changes in the refining industry, TDC retained Hycarb to study the availability and quality of fuels for both railway and marine diesel applications in Canada. The fuel types include middle distillate and residual products with current or modified specifications (if necessary) from petroleum refineries. Hycarb earlier completed a multiclient study, "Canadian Refining Outlook to 1992", to which TDC subscribed. This study was an integral part of the present TDC study, as individual product demand forecasts were adapted for this work. A subscription to this multiclient report is available from Hycarb.

The present study examines the capability of the Canadian refining industry in five regions to supply required volumes and quality of all refined products, particularly fuels to railway and marine diesel operators through to 1995. Hycarb used its in-house refinery linear program (LP) for this evaluation. It also examines commercial implications, such as product pricing, as well as possible research and development (R&D) options.

This report describes the approach, basis, refining analyses, product quality and prices. It presents specific considerations for railway and marine applications, followed by conclusions and recommendations. Detailed background data and forecasts are given in the Appendices.

2. APPROACH TO STUDY

An investigation into the availability of diesel fuel for the railway and marine diesel operators cannot be carried out in isolation from the total requirements for all petroleum products. A refiner produces a slate of products ranging from gasoline to heavy fuel oil (HFO). The production of one product line is interdependent upon the production of all other product lines. When a refiner adjusts refinery process operating conditions or selects new feedstocks to change the volume or quality specifications in one product line, it inherently affects the volume and quality of other product lines. It is, therefore, necessary to carry out the investigation in the context of not only availability of fuel type for specific consumers, but in the context of availability of supply of all petroleum products.

The primary parameters selected as a basis for this study include overall product slate, crude slate and refinery capacities/configuration. The basis for these forecasts is given later with the forecasts themselves. In general, these forecasts are adopted from the March, 1983, Hycarb multiclient study, "Canadian Refining Outlook to 1992", and modified for subsequent events such as additional refinery closures.

For purposes of the analysis, five geographical regions were considered: British Columbia, the Prairie Provinces, Ontario, Quebec and the Atlantic Provinces. Hycarb used its in-house refinery LP to model each region as a single large refinery. Each refining community was analyzed as to its ability to adjust operations to meet the demand requirements for petroleum products. The refining communities were constrained by availability of crude oil, current product specifications and the existing marketing and distribution systems. The refineries were based on existing refinery processing configurations plus refinery expansions and modifications which have been publicly announced as of November, 1983.

From the result of the refinery analysis, a supply outlook for petroleum products was provided. Shortfalls or surpluses in product availability and quality specifications were identified. Potential actions were then examined which could alleviate or reduce the constraints on the refining community, with particular emphasis on providing long-term supplies of fuel for railway and marine diesels.

3. REFINERY PRODUCTS

The product slate was adapted from the Hycarb study, "Canadian Refining Outlook to 1992". In that study, a "low demand" forecast was developed for each product in each refining region. In general, this was based on the low product demand experienced in 1982, and the low demand growth rates from the National Energy Board (NEB) report of June, 1981, "Canadian Energy, Supply/Demand: 1980-2000". Adjustments were made to reflect more recent changes, such as the effect of delays in installation of natural gas distribution facilities in eastern Canada and their effect on fuel oil demand.

Hycarb has reviewed this forecast with refining and government representatives. Although individual forecasts vary, this overall forecast seemed to meet with a concensus of agreement. In comparison with some recent forecasts, the demand forecasts in the present study may be slightly high for diesel fuel, and low for gasoline. However, for assessing diesel fuel supply capabilities, these forecasts should be conservative.

Based on the demand forecast, a regional production forecast was developed for each product to allow for refinery internal consumption, exports or imports of products, and transfers of product between regions.

A high demand sensitivity case was examined for 1995 in case of high economic recovery to determine whether the current refinery closures would constrain supply below demand.

3.1 Product Supply/Demand

Detailed forecasts of both production and demand for each product in each of the five regions are given in Appendix A. The major refined products include gasoline, jet fuel, diesel fuel, light fuel oil (LFO), kerosene, HFO and others. "Other" products include asphalt, lubricants, petrochemical feedstocks, naphtha specialties, liquefied petroleum gas (LPG) and still gas.

3.1.1 Western Canada

Table 1 summarizes the refinery production forecast for western Canada, including the Prairie Provinces, British Columbia, the Yukon and Northwest Territories.

Total production is not expected to return to the 1981 level, 83 thousand cubic metres per calendar day ($10^3m^3/cd$), until 1990, and the 1995 supply should reach approximately 88 $10^3m^3/cd$. Growth is expected to be strongest in diesel fuel, and to a lesser extent in jet fuel and "other" products. A decline is expected in gasoline, LFO and HFO.

to be strongest in diesel fuel, and to a lesser extent in jet fuel and "other" products. A decline is expected in gasoline, LFO and HFO.

In the 1995 high demand case, total production could be as high as 103 $10^3m^3/cd$. The demand trends are directionally the same as in the base case, except gasoline demand would recover to 1980/81 levels.

3.1.2 Eastern Canada

The refinery production forecast for eastern Canada, including Ontario, Quebec, and the Atlantic Provinces is also summarized in Table 1. Total production is expected to decline further from the 1982 level of 166 $10^3m^3/cd$ to 128 $10^3m^3/cd$ by 1995. This forecast is largely due to the loss of more than half the LFO and HFO markets to natural gas and electricity. The reduction in gasoline demand should also be significant. Some growth in demand is expected for asphalt, lubricants, jet fuel and especially for diesel fuel. Figure 1 shows the base case forecasts for product demand (including refinery consumption and exports).

In the 1995 high demand case, total production could be as high as 158 $10^3m^3/cd$, which is still below the 1982 level. Demand trends for each product are directionally the same as in the base case, but growth rates are higher.

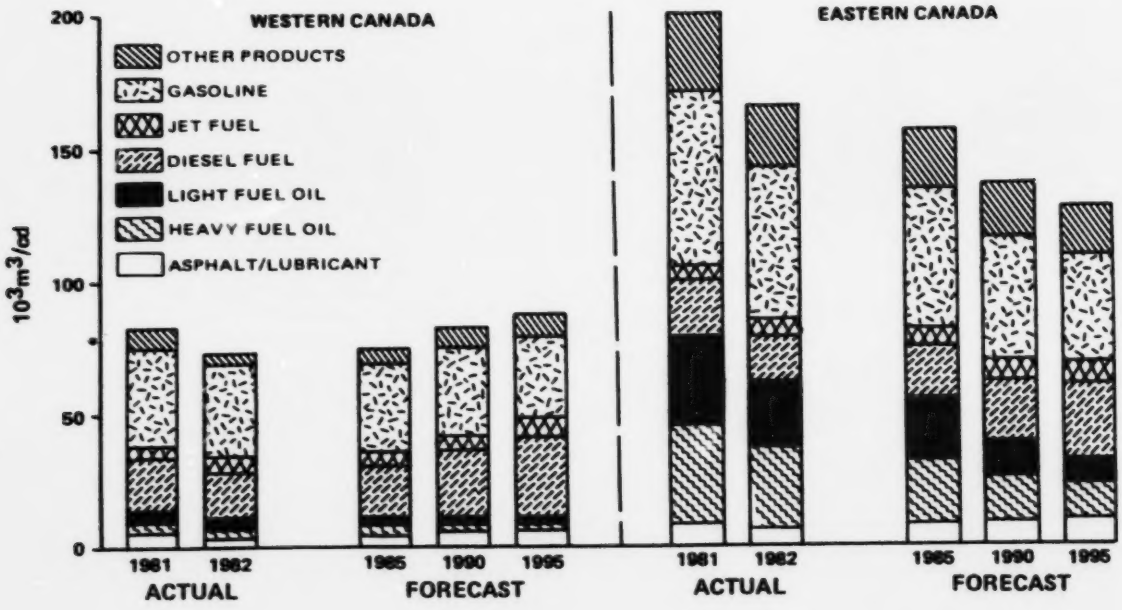

FIGURE 1 REFINED PRODUCT DEMAND (1)

NOTE: (1) INCLUDES REFINERY CONSUMPTION, EXPORTS AND INTER – REGIONAL TRANSFERS

3.1.3 Refinery Production

As noted earlier, refinery production forecasts are derived for each product based on product demand, refinery consumption, and interregional transfers. In this long range study, inventory changes as well as product exports or imports are assumed to be negligible. Refinery consumption is mostly HFO and still gas for plant fuel and typically represents more than 5% of crude throughput.

3.1.4 Product Distribution

Interregional transfers vary among products and regions. Historical and assumed future transfers are summarized in Appendix A, Table A-1. In British Columbia, product demand exceeds refinery capacity. In order to meet demand, about 4 10^3m^3/cd of product is transferred from the Prairie Provinces; transfers will likely continue at even higher rates, depending on the level of demand. Starting in 1984, Shell Canada Limited (Shell) plans to move semi-finished product from its new Scotford, Alberta refinery to its Burnaby, British Columbia refinery, via the existing Trans Mountain Pipe Line Company Ltd. (TMPL) pipeline for crude oil. TMPL has tested movement of finished product from Edmonton to Kamloops, and to the Vancouver area refineries but this operation is not yet commercial. The southeastern area of British Columbia is supplied by truck from Calgary. Conversely, the northwestern area of Alberta is supplied from Ft. St. John, British Columbia. Within the Prairies, considerable product is supplied from Edmonton to Regina and Winnipeg by Interprovincial Pipe Line Limited (IPL) and to Calgary by Alberta Products Pipeline Ltd. (APPL). Small movements (less than 1 10^3m^3/cd) of finished products are transferred from the Prairies into northern Ontario by truck or rail.

In eastern Canada, there are two product pipelines to carry product from Sarnia, Ontario as far as the Toronto area. The Trans-Northern Pipelines Inc. (TNPI) system can transport product to eastern Ontario, including Ottawa, from Toronto and Nanticoke, Ontario and from Montreal. Recently, the system has begun movements from Ontario to Montreal. During the navigation season, some product is moved by ship as well.

Historically, Quebec has produced about 3 10^3m^3/cd of extra product for transfer to eastern Ontario, including the Ottawa valley. However, with reduced capacity in Montreal due to three refineries closing, the Ontario refineries are expected to supply most of eastern Ontario, and transfer extra product (about 3 10^3m^3/cd) into the Quebec market.

In recent years, Quebec refineries have also supplied about 2 10^3m^3/cd by ship to the Atlantic region. On balance, this is expected to be discontinued, because of reduced capacity in Quebec, and overcapacity in the Atlantic region.

TABLE 1 REFINERY PRODUCTION
(Thousands of Cubic Metres Per Calender Day)

			Base Case			High Demand Case
	1981	1982	1985	1990	1995	1995
Western Canada(1)						
Gasoline	36.91	35.46	32.73	32.31	31.22	37.33
Jet Fuel	5.27	4.58	5.17	6.24	7.29	8.14
Diesel Fuel	19.38	17.82	19.92	25.09	29.85	33.15
LFO	4.80	4.28	3.47	3.07	2.56	2.82
HFO	5.31	4.13	4.45	3.87	4.03	4.79
Other	11.32	7.80	11.08	12.34	13.23	16.54
Total	82.99	74.07	76.82	82.92	88.18	102.77
Eastern Canada(2)						
Gasoline	66.37	58.24	53.23	47.97	41.75	50.36
Jet Fuel	7.31	6.33	6.25	7.12	7.83	8.85
Diesel Fuel	19.40	16.51	19.58	23.29	27.01	30.29
LFO	34.14	27.50	22.49	14.20	10.74	12.44
HFO	37.79	28.26	25.27	16.39	13.40	21.72
Other	34.92	29.21	27.16	26.81	26.79	34.61
Total	199.91	166.05	153.98	135.78	127.52	158.27
Canada						
Gasoline	103.28	93.70	85.96	80.28	72.97	87.69
Jet Fuel	12.58	10.91	11.42	13.36	15.12	16.99
Diesel Fuel	38.78	34.33	39.50	49.38	56.86	63.44
LFO	17.94	31.78	25.96	17.27	13.30	15.26
HFO	39.45	32.39	29.72	20.26	17.43	26.51
Other	46.24	37.01	38.24	39.15	40.02	51.15
Total	282.90	240.12	230.80	218.70	215.70	261.04

Notes: (1) Reference: Appendix A for Prairie Provinces, British Columbia and Territories.
(2) Reference: Appendix A, Ontario, Quebec, and Atlantic Provinces.

3.2 Diesel Fuel Demand

Table 2 presents the 1981 regional diesel fuel demand by end-use. In Canada, 60% of the demand for diesel fuel was in the transportation sector. Combined railway and marine diesel demand was approximately 40% of transportation diesel fuel demand. The agriculture, industrial and mining sectors also contributed significantly to 1981 diesel fuel demand.

With the exception of Quebec, total demand for diesel fuel is forecast to increase greatly in all regions to 1995. Regional diesel demand is shown in Appendix A. In western Canada, total diesel fuel demand is expected to increase from 19.9 10^3m^3/cd in 1981 to 30.3 10^3m^3/cd by 1995. Eastern Canada should also realize significant growth from 20.5 10^3m^3/cd to 27.1 10^3m^3/cd by 1995. Growth is expected to occur primarily in the road transportation sector.

Table 3 provides a further breakdown of diesel fuel demand in the railway and marine sectors. Historically, the Prairie Provinces and Ontario have shown the largest railway demand, comprising 70% of the 1981 national demand. Diesel fuel demand in the railway industry fell 10% between 1981 and 1982. The forecast demand is derived from data used for a draft report, "Regional Transport Fuel Demand Sensitivity", June, 1983, by Transport Canada (DGEA). Future growth is expected to be moderate with the industry regaining the 1981 Canadian demand level of 6.5 10^3m^3/cd by 1985. Moderate growth is expected to continue to 1990, but after that time, growth will be slower, reaching 8.1 10^3m^3/cd by 1995.

As in the railway industry, a significant decline in the demand for marine diesel fuel demand occurred in 1982. Canadian carriers consumed 78% of marine diesel fuel in 1981 and 1982. Forecast demand for marine fuels are also derived from the above DGEA report. However, marine diesel fuel requirements were adjusted downward, consistent with expected growth in marine bunker demand. Demand for diesel fuel in the marine sector is expected to grow slowly in all regions throughout the forecast period from 3 10^3m^3/cd in 1981 to 3.6 10^3m^3/cd in 1995.

Table 3 also shows demand for marine bunker fuel. On a Canada wide basis, demand fell 29% between 1981 and 1982 and recovery to 1981 levels is not expected until 1995 when demand is forecast to be 7.1 10^3m^3/cd. Marine bunker fuel demand represented 69% of the marine sector fuel demand in 1981 on a volumetric basis. Foreign carriers have consumed 31-38% of marine bunker in 1981/82; thus total bunker requirements can vary significantly with demand by foreign ships.

TABLE 2 DIESEL FUEL DEMAND BY END-USE - 1981(1)

(Thousands of Cubic Metres Per Calendar Day)

	British Columbia & Territories	Prairies	Ontario	Quebec	Atlantic	Canada
Electric Power Generation	0.51	0.28	-	0.24	0.11	1.14
Mining	0.81	1.03	0.20	0.69	0.28	3.01
Manufacturing						
Pulp and Paper	-	(2)	-	-	(2)	-
Iron and Steel	-	(2)	0.10	0.01	(2)	.11
Smelting and Refining	(2)	(2)	0.05	0.01	(2)	.07
Cement	(2)	(2)	0.05	0.04	(2)	.19
Chemicals	0.01	0.01	0.10	0.02	(2)	.14
Other Manufacturing	0.16	(2)	0.30	0.20	(2)	1.15
Total Manufacturing	0.20	0.41	0.60	0.28	0.17	1.66
Forestry	0.85	0.09	0.39	0.42	0.13	1.88
Construction	0.31	1.09	0.62	0.34	0.13	2.49
Transportation						
Rail	0.78	2.61	1.93	0.81	0.33	6.46
Marine	0.99	-	0.47	0.65	0.91	3.02
Road	2.16	4.32	4.18	2.99	1.30	14.95
Pipelines	0.05	0.06	-	-	-	.11
Total Transportation	3.98	6.99	6.58	4.45	2.54	24.54
Agriculture	0.22	2.60	0.60	0.57	0.20	4.19
Government(3)	0.47	0.37	0.21	0.33	0.44	1.82
Total Demand	7.35	12.87	9.20	7.32	4.00	40.74

Notes: (1) Source: Statistics Canada Catalogue 57-003.
(2) Data not available.
(3) Except electric power generation and transportation services.

TABLE 3 DEMAND FOR FUELS IN THE RAILWAY AND MARINE SECTORS
(Thousands of Cubic Metres Per Calender Day, Unless Otherwise Noted)

	1981		1982		Base Case		
	10^3m^3/cd	% Domestic(1)	10^3m^3/cd	% Domestic(1)	1985	1990	1995
Railway							
British Columbia and Territories	.78		.73		.71	.99	1.13
Prairie Provinces(2)	2.61		2.32		2.71	3.21	3.48
Ontario	1.93		1.82		1.87	2.14	2.19
Quebec	.81		.66		.84	.99	.97
Atlantic Provinces	.33		.28		.32	.31	.33
Total Canada	6.46	100	5.82	100	6.46	7.64	8.10
Marine Diesel Fuel							
British Columbia and Territories	.99	88	.88	84	.99	1.08	1.19
Prairie Provinces	–	–	–	–	–	–	–
Ontario	.47	75	.41	61	.51	.54	.54
Quebec	.65	66	.57	68	.80	.81	.86
Atlantic Provinces	.91	79	.77	86	.89	.95	1.01
Total Canada	3.02	79	2.63	78	3.18	3.38	3.60
Marine Bunker Fuel							
British Columbia and Territories	2.00	70	1.58	69	1.67	1.91	2.17
Prairie Provinces	–	–	–	–	–	–	–
Ontario	1.04	63	.71	72	1.07	1.15	1.22
Quebec	2.63	67	2.25	51	2.66	2.78	2.90
Atlantic Provinces	1.21	69	.34	85	.66	.73	.82
Total Canada	6.88	68	4.88	62	6.06	6.57	7.11

Notes: (1) Sales to Canadian marine carriers versus foreign carriers. Statistics Canada Catalogue 57-003.

(2) Supplied from tar sands: 1981, .80 x 10^3m^3/cd,
1982, .50 x 10^3m^3/cd,
1985-1995, .80 x 10^3m^3/cd.

3.3 Product Quality

Major product specifications used in this analysis are found in Appendix B (Product Quality), and Appendix E (Refinery Model). Important specifications and quality guidelines for diesel engine fuels are summarized in Table 4.

The "diesel fuel" specification applies to most road uses of diesel fuel, and is commonly referred to as "gas oil" in the marine sector. Whereas the railway operators previously followed a specification much like road diesel, they have now developed satisfactory guidelines which are generally satisfied by LFO (furnace oil). These guidelines are relaxed in areas of cetane, pour point and end point.

Specifications for marine diesel fuels are not yet available, but will be issued by the Canadian Government Specifications Board (CGSB) early in 1984. Specifications for naval distillates are available; the specification for -6°C pour fuel is given in Table 4.

The marine bunker specification has been concerned mainly with viscosity to date. Other properties are presently being considered to better protect marine engines and systems. This is discussed later.

T A B L E 4 DIESEL ENGINE FUEL SPECIFICATIONS

	Diesel Fuel[1] Type A	Diesel Fuel[1] Type B	Railway Diesel Fuel	Naval Distillate[3]	Bunker (HFO)[4]
Minimum Flash, °C	40	40	40	60	60
Maximum Viscosity, CS at 40°C	4.1	4.1	4.5	4.4	648 (at 50°C)
Minimum Viscosity, CS at 40°C	1.3	1.4	1.6	1.7	92 (at 50°C)
Maximum Pour Point, °C	-39	(5)	(6)	-6	-
Maximum Cloud Point, °C	-34	(5)	(5)(8)	-1	-
Minimum Cetane Number	40	40	30	40	-
Maximum Sulphur, wt. %	0.5	0.7	0.5	1.0	(9)
Maximum 90% Recovered, °C	315	360	345[10]	335	-

Notes:
(1) CGSB-CAN2-3.6-M83.
(2) CN Rail guideline. Reference: ASME 83 DGEP-3, D. R. Jackson and W. G. Blevins.
(3) CGSB - 3GP - 11M.
(4) CGSB-CAN2-3-M81.
(5) 2.5% Low End Design Temperature.
(6) To be reported.
(7) -18°C for cold environment.
(8) Flow test, rather than cloud point.
(9) May be stipulated by contract or government regulation.
(10) Can be higher if other guidelines satisfied.

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4. CRUDE OIL

The supply of Canadian crude oil was also forecast in the Hycarb multiclient study. This is generally based on the 1981 NEB report, as well as Alberta Energy Resources Conservation Board (ERCB) and Saskatchewan Ministry of Energy and Mines publications. It includes some modifications to reflect cancellation of tar sands projects, and delays in Canadian offshore production.

The total product supply forecast in each region provides the basis for a regional crude demand forecast. The Canadian supply of crude oil is allocated to specific regions based on total crude supply/demand, pipeline capabilities, previous history, expected changes and regional priorities. As supply of western Canadian crude oil declines, less will be available for Quebec, but east coast offshore crude should become available to the Atlantic region as well as Quebec. Any crude oil shortfalls in eastern Canada are assumed to be made up by imports of foreign crude oil.

A sensitivity case was examined for 1995, when the possibility of additional synthetic crude production exists.

4.1 Crude Oil Supply/Demand

Based on the total product supply forecast for each region, a refinery crude oil demand forecast is developed as summarized in Table 5. Growth in crude oil consumption is expected only in the Prairie Provinces.

T A B L E 5 CRUDE OIL DEMAND
(Thousands of Cubic Metres Per Calender Day)

			Base Case			High Demand Case
	1981	1982	1985	1990	1995	1995
British Columbia and Territories	26.8	25.0	23.8	25.7	26.4	26.4
Prairie Provinces	53.1	48.1	49.8	53.7	58.2	71.8
Ontario	87.9	75.7	73.9	70.1	67.3	78.6
Quebec	75.4	65.9	50.1	42.9	38.8	52.3
Atlantic Provinces	34.2	22.2	28.4	21.5	20.2	25.9
Total	277.4	236.8	226.0	213.9	210.9	255.0

A detailed crude oil supply forecast is given in Appendix C. Table 6 provides a summary. Most western Canadian crude production will decline except for heavy, and synthetic crudes. The increase in synthetic crude is assumed to be produced from an 8 $10^3m^3/cd$ heavy crude upgrader before

1990. Frontier crude from Canada's offshore east coast and/or the Beaufort Sea is assumed to come onstream by 1990, and reach full production of 56 10^3m^3/cd by 1995. In the "high supply" case, an additional 20 10^3m^3/cd of synthetic crude is assumed to be available by 1995 from additional heavy crude upgrading or from tar sands.

Table 6 also summarizes the forecast crude supply/demand balances. On balance, Canada could be near self-sufficiency in crude oil for the next few years, as heavy crude production increases. Self-sufficiency would then be lost, but potentially regained in the 1990's if frontier crude becomes available. In the high demand case, self-sufficiency would not be possible with expected frontier production volumes; so additional synthetic crude production would be needed.

The crude oil supply/demand balance is shown in Figure 2. In this chart, domestic crude supply within Canada is availability after deduction of probable exports. The shortfall in crude supply must be met by imports.

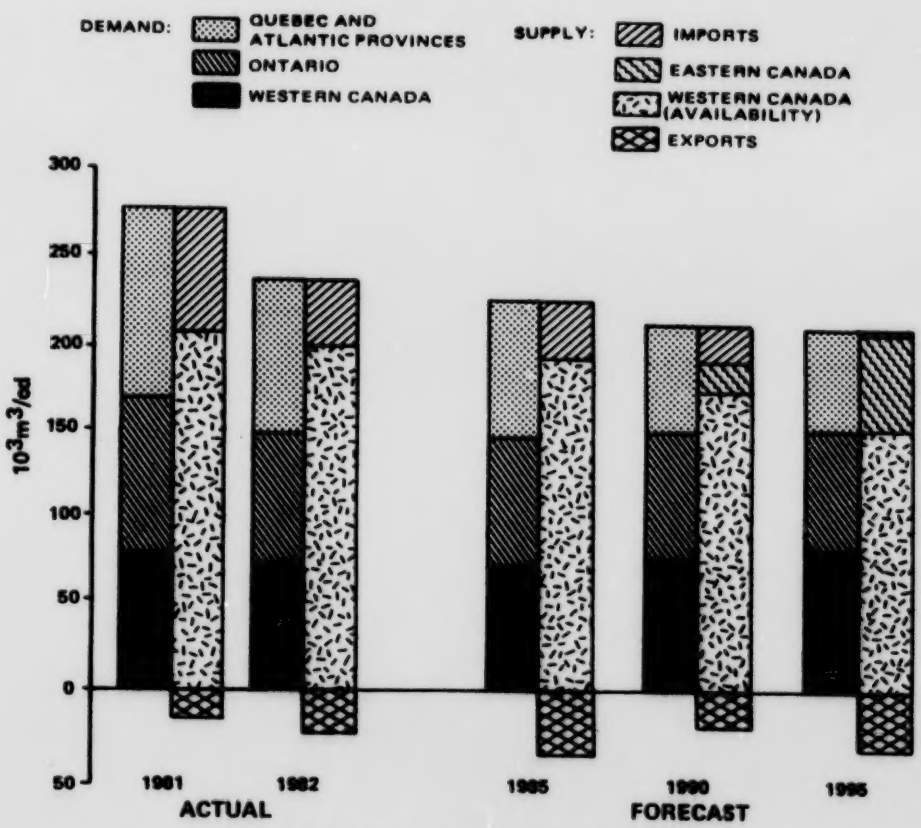

FIGURE 2 CRUDE SUPPLY / DEMAND

TABLE 6 CRUDE OIL SUPPLY/DEMAND BALANCE
(Thousands of Cubic Metres Per Calender Day)

	Actual Production		Base Case			High Demand Case	High Supply Case
	1981	1982	1985	1990	1995	1995	1995
Supply							
Light	159.8	149.9	139.4	107.2	88.7	88.7	88.7
Pentanes Plus	10.4	12.9	11.2	8.7	8.6	8.6	8.6
Medium/Heavy	32.3	31.0	44.6	35.8	39.0	39.0	39.0
Bitumen	1.0	.8	3.4	3.7	3.8	3.8	3.8
Synthetic	16.2	21.2	28.0	36.0	36.0	36.0	56.0
Frontier	-	-	-	14.3	56.0	56.0	56.0
Total	219.7	215.8	226.6	205.7	232.1	232.1	252.1
Demand							
Domestic	277.4	236.8	226.0	213.9	210.9	255.0	210.9
Import - Light/Medium	68.0	39.1	28.7	23.4	2.7	39.3	-
- Heavy	4.0	5.6	4.0	4.0	7.0	7.0	4.0
Subtotal Import	72.0	44.7	32.7	27.4	9.7	46.3	4.0
Export - Light	.8	5.7	-	-	7.0	-	24.9
- Medium/Heavy	13.5	17.9	33.3	19.2	23.9	23.5	20.4
Subtotal Export	14.3	23.6	33.3	19.2	30.9	23.5	45.3

A significant amount of Canadian heavy crude is exported to the United States (U.S.) because the volume available exceeds the processing capabilities of Canadian refineries. Because of heavy crude exports, some import of foreign crude oil will likely be needed throughout the forecast, but at levels considerably below the 1981 level.

4.2 Crude Oil Allocation

Based on the crude oil demand pattern of Table 5 and the supply of crude oil from western Canada and eastern Canada (frontier), each type of crude oil has to be allocated among the five regions, with shortfalls made up from imports. Results of the crude oil allocation are given in Appendix C for the base case as well as 1995 sensitivity cases (high demand, and high supply).

In the Prairie Provinces, the use of synthetic crude is expected to increase because of new processing capabilities in this region. Montreal refineries receive foreign crude oil via the Portland Pipeline (Portland) system. In Quebec, the use of foreign crude was greatly reduced in 1982, because of the availability of Canadian crude. Some Canadian crude was shipped to the Atlantic via Montreal. This helped the Portland pipeline maintain minimum flow rates of crude oil. In the future, exchanges of western Canadian crude for foreign crude may be needed to maintain Portland pipeline operations. By 1995, there will likely be insufficient western Canadian crude available for Ontario, unless additional synthetic crude comes onstream; then all of Quebec's crude oil needs will be met from east coast offshore crude or foreign crude. The level of foreign crude will depend on demand as well as domestic supply. The shortfall in Ontario in the 1995 base case (2.7 10^3m^3/cd) is assumed to be made up by foreign crude supplied via U.S. pipeline systems. In the 1995 high demand case, Ontario would need 24.2 10^3m^3/cd of frontier and/or imported crudes.

The Atlantic refineries are expected to continue using mostly foreign crude oil until offshore crude becomes available.

5. REFINING CAPACITY

For each refining region, the total capacity of each major refining process was identified for 1981, based on Hycarb records from published data and other sources. These capacities have been modified for 1985 and beyond to reflect announced refinery expansions, modifications, reductions, and closures.

Based on expected crude demand, and effective crude capacity, refinery utilization was also determined.

5.1 Refinery Capacity

A detailed listing of major unit capacities for each refinery is given in Appendix D. Table 7 is a summary of all refineries by region showing effective crude capacities in 1981 and beyond 1985.

In 1981, there were 36 refineries operating in Canada with a total crude capacity of 336.8 10^3m^3/cd. At that time, major expansions were underway in the Prairie region, and two grass roots refineries will have come onstream by 1984 (Turbo Resources Limited (Turbo) and Shell, Scotford).

However, demand for products has fallen sharply as noted earlier, and extensive refinery rationalization is taking place. Since mid-1982, the closure of nine refineries has been announced, representing 57.0 10^3m^3/cd of crude capacity, 63% of which is in Quebec. By 1984, the shutdown refineries will include Ultramar Canada Inc. (Ultramar), (Holyrood), BP Canada Limited (BP), Esso Petroleum Canada (Esso), Texaco Canada Inc. (Texaco), (Montreal area), Shell (Oakville and St. Boniface), Texaco (Edmonton), and Gulf Canada Limited (Gulf), (Calgary and Kamloops). Partial shutdowns are taking place at Gulf (Clarkson and Montreal East) and Irving Oil Ltd. (Irving), (St. John). Other rationalization at Petrosar Limited (Petrosar) and Suncor Inc. (Suncor) (Sarnia) and Ultramar (St. Romuald) will reduce HFO yields and thus reduce crude demand and effective crude capacity.

TABLE 7 REFINING CRUDE CAPACITY
(Thousands of Cubic Metres Per Calendar Day Unless Otherwise Noted)

	1981		1985-1995	
	Number	Capacity	Number	Capacity
British Columbia and Territories	8	27.3	7	26.4
Prairie Provinces	9	58.9	8	71.3
Ontario	8	107.8	7	80.2
Quebec	7	97.8	4	63.4
Atlantic Provinces	4	45.0	3	35.7
Total	36	336.8	29	277.0

The changes will result in an increase of 11.5 $10^3m^3/cd$ of crude capacity in western Canada, and a decrease of 71.3 $10^3m^3/cd$ in eastern Canada. The remaining 29 refineries will have a total crude capacity of 277 $10^3m^3/cd$.

Diesel fuel production facilities are being improved in the Prairie refineries. Esso has installed additional hydroprocessing to remove wax and improve pour point. Gulf has installed a hydrotreater to improve the cetane number of middle distillate in synthetic crude; Shell is installing a similar unit at the new Scotford refinery. In Ontario, diesel fuel production could be enhanced by the recommissioning of Esso's hydrocracker, and the installation of Suncor's new hydrocracker.

5.2 Refinery Utilization

Refinery utilization measures crude throughput as a percent of effective crude capacity. The historical and forecast utilization is given in Table 8 for each refining region based on the total crude demand and effective crude capacity given in Tables 6 and 7 respectively.

The low utilization of 1982 shows the need for the refinery closures which were announced. Utilization remains fairly high in British Columbia, because product demand exceeds refinery capacity. Utilization in the Prairie region is expected to decline further in 1984 when the last of the new capacity (Shell, Scotford) comes onstream, but should improve after that.

In eastern Canada, rationalization to date may allow remaining refineries to continue operations for the next few years. However, as product demand and crude throughput continue to decline, more closures may be needed, unless additional export markets can be found. At present, an Atlantic refiner is processing approximately 10 $10^3m^3/cd$ of foreign crude oil for the U.S. market. If sustained, this type of operation could allow continued operations in this region. This level of processing would increase overall regional refinery utilization beyond 90%.

The combined utilization of Ontario and Quebec is expected to be about 86% in 1985 falling to 74% by 1995. This could require another closure by that time.

In Ontario and Quebec, refinery utilization and crude running are in part dependent on product transfers between these provinces. Because of refinery closures in Quebec, forecast product demand exceeds refining capacity. Some operators indicated their intent to move more product into Quebec. Actual transfers will depend on the extent of exchange and/or processing agreements between refiners; these are commonly employed to minimize distribution costs.

Figure 3 illustrates refinery crude throughput versus capacity for eastern and western Canada.

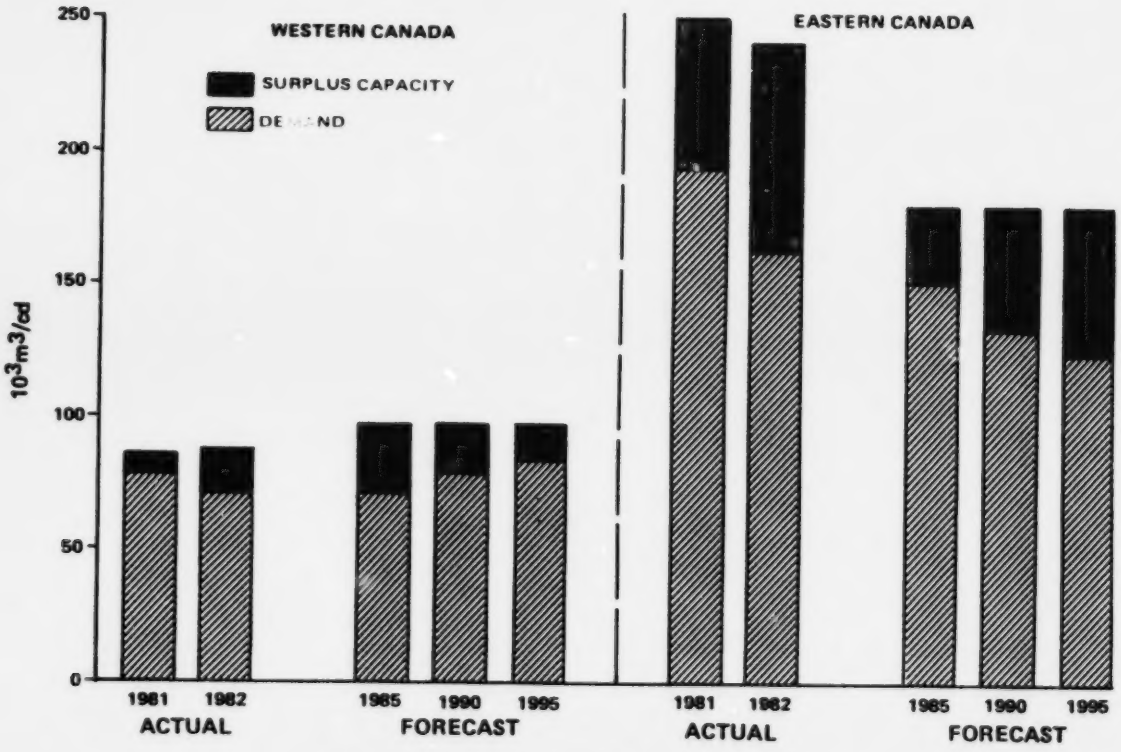

FIGURE 3 REFINERY CRUDE DEMAND/CAPACITY

TABLE 8 REFINERY UTILIZATION(1)
(Percent)

	1981	1982	Base Case 1985	Base Case 1990	Base Case 1995	High Demand Case 1995
British Columbia and Territories	98.2	89.5	90.0	97.2	100.0	100.0
Prairie Provinces	90.2	80.6	69.9	75.3	81.6	100.0
Ontario	81.5	70.2	92.2	87.4	83.9	98.0
Quebec	77.1	67.4	79.0	67.7	61.2	82.5
Atlantic Provinces	76.0	58.6	79.3	62.7	56.4	72.2
Western Canada	92.7	83.4	75.3	81.3	86.6	100.0
Eastern Canada	78.8	67.2	85.0	75.0	70.4	86.9
Ontario and Quebec	79.4	68.9	86.4	78.7	73.9	91.2
Canada	82.4	71.5	81.6	77.2	76.1	92.0

Note: (1) Crude demand (Table 5) as a per cent of effective crude capacity (Table 7).

6. REFINING ANALYSIS

For each of the refining regions, Hycarb modelled a single large refinery using its in-house refinery LP. A general description of the LP is given in Appendix E. The LP was calibrated by modelling each region in 1981, and then used for 1985, 1990, and 1995. Sensitivity cases were analyzed in 1995 for high product demand, and high synthetic crude supply.

The bases were the product supply, crude allocation, and refinery configuration discussed above. Details of these are given in Appendices A, C, and D respectively.

Generally, the result of the refining analyses is a supply for petroleum products with current specifications. Shortfalls or surpluses of product volumes were identified. Where potential problems are recognized, changes such as relaxation of product specifications are examined.

6.1 Product Slate Changes

Detailed product supply forecasts are given in Appendix A for each region. The forecasts were summarized in Section 3 for eastern and western Canada. Refineries must be capable not only of handling the future throughput requirements, but of producing a slate of products with changing proportions of individual products.

The expected changes in product slate in eastern Canada are shown in Table 9. Although total demand is expected to decline, the proportion of gasoline is expected to remain nearly the same. Diesel fuel is expected to increase greatly in proportion to other products, while LFO and HFO decrease. On balance, the gasoline/distillate ratio is expected to fall by 10-15%. The product slate distribution forecasts in 1995 are similar for the base case and the high demand case. Although product slate distribution should change over time, potential incremental production (i.e. high demand) is not expected to alter this distribution significantly.

For western Canada, the expected product slate changes are also shown in Table 9. Here, LFO and HFO production is low. The major changes are an increase in the proportion of diesel fuel and a corresponding decrease in gasoline. Again, the product slate distribution forecasts in 1995 are similar regardless of total product demand.

The changes expected in the gasoline/distillate production ratio in western Canada are significant. Where the gasoline/distillate ratio is presently the highest in Canada, it will become lowest.

TABLE 9 PRODUCT SLATE DISTRIBUTION
(Percent of Total Unless Noted)

	1981	Base Case 1995	High Demand Case 1995
Eastern Canada			
Gasoline	33.2	32.7	31.9
Jet Fuel	3.7	6.1	5.6
Diesel Fuel	9.7	21.2	19.1
LFO	17.1	8.4	7.9
HFO	18.9	10.5	13.7
Other	17.4	21.0	21.9
Total	100.0	100.0	100.0
Gasoline/Distillate Ratio(1)	1.09	0.92	0.98
Western Canada			
Gasoline	44.4	35.4	36.3
Jet Fuel	6.4	8.3	7.9
Diesel Fuel	23.4	33.8	32.3
LFO	5.8	2.9	2.7
HFO	6.4	4.6	4.7
Other	13.6	15.0	16.1
Total	100.0	100.0	100.0
Gasoline/Distillate Ratio	1.25	0.79	0.85

Note: (1) Distillate = Jet Fuel + Diesel Fuel + LFO.

6.2 British Columbia and Territories

As noted earlier, the refineries in British Columbia are expected to return to full capacity as demand increases, since total demand in the province will exceed capacity. Major changes in the demand for individual products will likely be accommodated from Prairie Provinces refineries.

In the LP analysis for each year, the forecast volumes of each product could be produced from the available crude slate.

6.3 Prairie Provinces

The Prairie Provinces refineries will have sufficient capacity for the

forecast period, although utilization would approach 100% in the high demand case in 1995. The product slate will undergo a significant shift to diesel fuel. LFO and HFO markets in the Prairie region are negligible.

LP analyses indicate that the Prairie Provinces refineries will be capable of meeting all product requirements until 1990. By the early 1990's, Prairie Provinces refineries could have difficulty producing diesel fuel without an excess of light products such as gasoline or naphtha. The lower cetane requirements of railway and some marine diesel fuels in British Columbia will assist refiners in maximizing distillate production while minimizing gasoline or naphtha production. In this analysis, 4.4 10^3m^3/cd of 35 cetane index diesel fuel was produced for use within the Prairie Provinces and for transfer to British Columbia; nevertheless, 0.9-1.9 10^3m^3/cd of excess naphtha was produced. This naphtha was assumed to be transferred to Ontario for petrochemical feedstock, but could be used as diluent for heavy crude oil. Alternately, gasoline could be produced for export from the region. If justified, additional processing could be installed, either hydrocracking to improve middle distillate yield and quality, or severe hydrotreating of fluid catalytic cracking (FCC) cycle oils to improve middle distillate quality.

Because of the high proportion of synthetic crude in the crude slate, as well as the presence of cokers and asphalt plants, production of surplus HFO is not expected to be a problem.

6.4 Ontario

The Ontario refining region is expected to become a net exporter of product to Quebec, but refinery capacity will not be fully utilized. Crude supply is expected to be stable until 1990, but by 1995 some imported and/or frontier crude will likely be needed, especially in the high demand case. Most imported crudes and the likely frontier crude are heavier than Alberta light crude; so HFO production could increase by 1995. Current modernizations at Suncor and Petrosar will allow HFO production to be reduced considerably.

LP analyses indicate that all product requirements can be met in Ontario throughout the forecast period. Supply of naphtha from the Prairie Provinces may reduce refinery naphtha production requirements in Ontario. Although all required HFO can be produced, refiners will have the capability to reduce HFO production further in the mid-1980's. In the 1990's, there should be a surplus (up to 2.5 10^3m^3/d) of HFO in Ontario beyond the expected requirements.

6.5 Quebec

The Quebec community has experienced the greatest change in terms of refinery shutdowns. It is now expected to become a net importer of product from Ontario and perhaps the Atlantic region. Montreal area refineries receive crude oil from western Canada, and from outside North America.

These refineries generally accept as much Canadian light crude as possible while balancing total crude requirements with foreign crude. Quebec refineries have experienced considerable changes in crude slate, and more changes are expected as summarized in Table 10.

Availability of western Canadian light crude will diminish, but so will imports as total crude throughput falls further. By 1990, east coast offshore crude could appear in Montreal, and become the predominant crude by 1995. This crude is assumed to be 32°API and 1 weight percent sulphur (wt.% S) with middle distillate quality similar to conventional Canadian light crude (Appendix E). Western crude would not likely be available in Montreal by 1995, unless more synthetic crude production comes onstream the high supply case).

HFO production will depend largely on the quality of imported and frontier crudes and on the availability of synthetic crude. Modernizations at Ultramar and Petro-Canada could greatly reduce HFO production.

The LP analyses indicate that all the product requirements can be met in Quebec throughout the forecast period. All HFO requirements can be met; however, refiners will be capable of reducing HFO production further throughout the 1980's.

TABLE 10 QUEBEC CRUDE SUPPLY(1)
(Thousands of Cubic Metres Per Day)

	1981	1982	1985	1990	1995	High Supply 1995	High Demand 1995
Western - Light(2)	25.2	29.5	26.2	8.9	-	3.9	-
- Medium/Heavy	6.9	3.5	2.6	2.8	-	3.0	-
- Pentanes Plus	.9	.9	1.0	2.0	-	2.0	-
- Synthetic	4.6	4.7	8.0	9.0	-	9.0	-
Subtotal	37.6	38.6	37.8	22.7	-	17.9	-
Frontier	-	-	-	7.2	32.9	18.0	27.5
Import	37.8	27.3	12.3	13.0	5.9	2.9	24.7
Total	75.4	65.9	50.1	42.9	38.8	38.8	52.3

Notes: (1) Derived from crude oil allocations in Appendix C.
(2) Includes exchanges.

6.6 Atlantic Provinces

The Atlantic refineries normally use foreign crude, although up to 8 10^3m^3/cd of western Canadian crude has been shipped to the region via

8 10^3m^3/cd of western Canadian crude has been shipped to the region via Montreal since 1982. The foreign crude slate is expected to dominate until east coast offshore crude becomes available in the 1990's.

The LP analyses indicate that all product requirements can be met throughout the forecast period. All HFO can be produced if needed, but refineries have the capability to maintain production below demand in the mid-1980's. By 1990, a small HFO surplus (1 10^3m^3/d) could develop.

6.7 Product Balance

With only a few exceptions, the refining community in all regions are expected to meet product requirements. Potential imbalances are shown in Table 11.

The shortfalls in HFO production are potential, but refiners could produce all the required volumes if there is sufficient incentive. With the HFO market in tight supply in the mid-1980's, prices may be forced upward. In the early 1990's, a surplus of HFO could develop, forcing the relative price of HFO down again. Pricing is discussed in Section 8.

The naphtha imbalance in Table 11 is peculiar to the Prairie region product slate and refinery processing. It is manageable by transfers out of the region. Alternative products such as gasoline could be produced and exported.

Across Canada, and until at least 1995, the refining industry should be able to supply diesel fuel for railway, marine and other uses, while producing required volumes of all other refined products as well. There may be individual refineries which encounter specific limitations. Seasonal variations in product demand may cause or aggravate product imbalances so that more seasonal storage would be required.

TABLE 11 PRODUCT SURPLUS
(Thousands of Cubic Metres Per Day)(1)

	Base Case			High Supply	High Demand
	1985	1990	1995	1995	1995
HFO					
Ontario	(1.7)	0.5	2.0	1.1	2.5
Quebec	(5.3)	(2.0)	(0.1)	(1.8)	0.2
Atlantic Provinces	(4.4)	1.0	0	0	(0.5)
Total	(11.4)	(0.5)	1.9	(0.7)	2.2
Naphtha					
Prairie Provinces	0	0	1.9	1.4	0.9
Ontario	0	0	(1.9)	(1.4)	(0.9)
Total	0	0	0	0	0

Note: (1) Brackets () indicate maximum potential shortfall.

7. DIESEL FUEL QUALITY

The major specifications for diesel, railway, and marine fuels were summarized in Table 4, and discussed in Section 3.3.

All of the initial analyses in this study were based on current product quality specifications, except for leaded gasoline, for which the tetra-ethyl-lead (TEL) content was reduced from 0.77 grams per litre (g/l) to 0.44 g/l in anticipation of reductions in allowable TEL content.

In most cases, the specifications for all diesel fuel production were for road diesel. The only exception was for the Prairie region in 1995 where a lower cetane specification (35 cetane index) was used for 4.4 $10^3m^3/d$ of railway and marine fuel. Based on the analyses discussed in Section 6, an overall problem of diesel fuel supply or quality is not anticipated in Canada during the forecast period.

Changes in fuel quality specifications for diesel engines are being considered. These may enhance refinery flexibility, but are not absolutely necessary from the supply perspective.

Some specific refiners may have more processing and/or marketing flexibility than others to adapt to the changing product slate. Other refiners may find it desirable to revise product specifications. Railway operators have found LFO (furnace fuel) to be an acceptable fuel for locomotives. Since the LFO market for space heating is declining, some refiners have been able to co-operate with the railways in supplying LFO instead of road specification diesel fuel. This has allowed the consumer to reduce fuel costs.

7.1 Special Products

Substitution of existing fuels such as the railway use of LFO can be readily accommodated by the refining industry. However, the use of new products, may be more difficult and costly. For instance, changes in boiing range could require changes within refinery process units to isolate the desired streams. For any new products, separate storage, pumping and handling systems may be required within the refineries, and within the supply/distribution and marketing systems. On the other hand, because of low utilization and the desire to minimize inventories, some refineries may have surplus tankage and handling systems which could be put into a new service at little or no cost.

7.2 Additives

The use of additives varies among refiners, and sometimes with

consumer specifications. For diesel fuel, pour point depressants are often used to improve handling, but these do not improve cloud point to the same extent. Cloud point can be improved with flow improvers. Use of cetane improvers (often organic nitrates) is increasing. These are more effective with high cetane stocks than with low cetane stocks; nevertheless, they can improve the overall diesel blend quality.

7.3 Cetane

As noted, railways are successfully using LFO fuel with cetane numbers in the low 30's. Some other medium speed diesels are found in the marine industry and electric power generation. These could potentially use lower cetane fuel as well.

The majority of diesel fuel consumption is for high speed engines, such as trucks. These engines require the current high cetane fuel (40-45 cetane number depending on location and season). Other Transport Canada/ Energy Mines and Resources studies are underway to determine whether lower cetane specifications can be tolerated. A reduction of about two cetane numbers may be possible. This would be significant because of the large volumes involved.

The cetane number of diesel fuels in Canada has often exceeded specifications, because of the middle distillate quality of many common crude oils used, and the ability of refiners to bury low cetane middle distillates in LFO and as cutter stock in HFO. As the demand for LFO and HFO falls, the cetane number of diesel fuel is expected to approach the specification. This will increase the attention to quality monitoring and control.

The accuracy of the cetane engine test (ASTM D613) is plus or minus two; this will become more significant as the actual cetane number of diesel fuel falls. ASTM is working to improve the procedure. The engine test is time consuming, and the number of cetane engines in Canada is limited. The CGSB has introduced a "Canadian Cetane Index" which improves the approximation of cetane number for cracked and synthetic middle distillates from previous methods. It is a correlation of gravity, aniline point, and viscosity. However, the applicability of cetane number for measuring the ignition quality of various fuels including cracked stocks for a variety of diesel engine types is questionable. The Co-Ordinating Research Council (CRC), sponsored by ASME and API, is evaluating the problem.

To ensure future compatibility between fuel components and engines, consideration of the applicability of diesel fuel ignition quality procedures should be continued in order to improve prediction of diesel fuel properties, and quality control.

7.4 Pour Point/Cloud Point

Pour point is specified for most diesel fuel applications to allow handling within the supply and distribution systems, including terminals and sales outlets, as well as onboard the consumers' operating equipment. It varies with location and seasonally with climate. Pour point can be depressed with additives. Cloud point is the temperature at which wax crystals begin formation. Wax deposits can plug filters on engine systems. However, wax crystal growth can be inhibited with flow improvers. Filterability tests are being developed to facilitate the use of flow improvers while providing adequate protection. The cloud point specification also varies according to local climate.

Conventional winter grade diesel must use low pour stocks which are needed for jet fuel as well. In winter, the high pour stocks have fewer uses in product, so are sometimes stockpiled for summer diesel, or cracked to gasoline. At least one refinery, Esso near Edmonton, has installed facilities to dewax middle distillate and improve pour point.

CN Rail no longer specifies pour point, as their off-track handling systems and locomotives have been modified to handle stocks which the refiners themselves can handle. They are installing hot wells (preheaters) in their locomotive fuel tanks. They still have requirements for cloud point (filterability at ambient temperatures); specifications; after all hot wells are installed in 1984, cloud point will not have to be specified, but a depressed pour point specification will then be required. This relaxation on cloud and pour points may allow some refiners to increase diesel fuel sales, particularly in winter.

Coastal marine operators using diesel fuel should not require stringent pour point specifications because of a more temperate environment. However, refiners in coastal locations generally produce different pour grades for interior versus coastal use.

Pour point and cloud point of diesel fuel increase with end point. However, by increasing end point, refiners can increase diesel fuel yield. For instance, the yield of straight run diesel fuel from Alberta light crude could increase by 3% of crude, or approximately 10-15% of diesel fuel by increasing diesel fuel end point from 343 to 357°C. Also cetane number would improve.

Much of this 343-357°C material is cracked to gasoline and LFO, but as both gasoline and LFO demand fall, and diesel fuel demand rises, particularly in western Canada, refiners may prefer to use this material in diesel fuel. (Fractionation changes could be needed.) Consumers with the capability of handling the higher pour point material, and tolerating the higher cloud point could mutually benefit with refiners.

7.5 Flash Point

Flash point in a measure of the temperature at which a diesel fuel

will ignite in the presence of an open flame. Flash points of fuel are specified for safety reasons. The present specification for automotive and railway diesel is 40°C. The specification for naval and international marine use is 60°C. Marine diesel for use in Canada has a minimum flash point specification of 43°C. Automotive diesel specifications were reduced from 52°C in recent years. This allowed a higher yield of middle distillate production by allowing lighter stocks to be blended into diesel fuel. Kerosene jet fuel (Jet A) has a minimum flash point of 38°C.

A further reduction in diesel fuel flash point could increase potential availability, but the light stocks would compete with jet fuel and gasoline requirements. Also, such a change would increase risk to safety, so is considered unlikely.

7.6 Heavy Fuel Blends

Much of the marine industry uses HFO which is blended with LFO to meet various viscosity specifications. Most refiners serving the marine industry on the sea coasts or on the Great Lakes have bunker blending systems at the dock for direct fuelling or for cargo loading to distribute to other marine terminals. Thus most marine operators can have access to HFO blends of almost any proportion.

Railways are considering bunker blends of approximately 10% HFO. This would represent a new product for many refiners. Although they likely have blending facilities available, they may not have storage and handling facilities to make the new product available. Some refiners may need new or modified facilities. On the other hand, modifications could be minor for some refiners who have spare tankage available. Alternatively, railways could receive conventional railway diesel and HFO, and provide their own storage and blending facilities.

8. PRODUCT PRICING

In the marketplace, actual product prices are determined by forces of supply and demand and competition. To forecast future prices of petroleum products, Hycarb assumes equilibrium pricing relationships in which refiners recover operating costs, including crude oil acquisition and margin.

To determine product prices, crude oil acquisition costs are needed. Based on a price forecast for world crudes (eg. Arabian Light), Hycarb uses an in-house model to determine refinery gate crude oil costs in each region of Canada. This model is based on the landed costs of imported crude at Montreal, the Canada-Alberta Energy Pricing Agreement (EPA) amended in July, 1983, crude oil pipeline tariffs, and the crude oil allocation discussed earlier. The EPA is assumed to extend beyond 1986, the actual expiry date. The EPA requires a forecast of domestic "old oil" and "new oil" volumes, and provides price differentials based on crude oil quality.

Based on the crude oil acquisition cost, and an estimate of other refinery operating costs and margins, an average realization from all refined products is determined. Because of the interdependence between refinery product slate, crude slate, and refinery processing capabilities, the price of each product must carry some portion of operating costs. Not all products carry the same level of costs. In fact, the price of HFO is normally less than crude oil; so other products must recover the loss on HFO.

To forecast prices of individual products, a realization ratio method is used. The price of one product can be expressed as a ratio of the average realization from all products. The realization ratio for each major product is forecast based on historical trends in realization ratio and future trends in refinery yield for each product.

8.1 Crude Oil Pricing

A forecast of Canadian crude oil prices was developed from a forecast schedule of international crude prices for Arabian Light marker crude. Although this crude was priced at $34.00 (U.S.) per barrel (B) FOB in 1982, the price fell to $29.00 (U.S.)/B FOB in 1983. As shown in Table 12, the expected annual nominal price changes of the Arabian Light crude will be 3% in 1985, 6% between 1986 and 1990 and 7% between 1990-95.

TABLE 12 CRUDE OIL PRICE PROJECTIONS
(Percent per year)

	Real Price Changes	Inflation	Current Price Changes
1984	(4)	4	0
1985	(2)	5	3
1986-90	0	6	6
1990-95	1	6	7

The average Canadian CIF import price was determined from the forecast of international crude oil prices and the Canadian import mix. Table 13 shows this price increasing from $271.29/m^3$ in 1981 to $411.87/m^3$ in 1995. Although the average Canadian import price is expected to be higher than the marker crude until 1990, the average price should later fall below the Arabian Light price, since imported crude is then assumed to be heavy crude for asphalt production.

Canadian domestic crude oil prices are related to the average imported crude oil price at Montreal, forecast volumes of "new oil" and "old oil", and "old oil" price differentials for crude oil quality. Table 13 shows the Montreal blended crude oil price increasing from $173.29/m^3$ in 1981 to $415.64/m^3$ in 1995. The Canadian blended crude oil price will approach world price levels over the forecast period as "old oil" production declines.

Average refinery gate crude oil acquisition costs are also shown on Table 13 for each region. These prices represent the weighted average cost of all crude oils in the region. They are developed from the Montreal refinery gate costs, adjusted for pipeline transportation costs. Average refinery gate prices differ between regions depending on the distance from the domestic oil supply (primarily Alberta) and the regional crude oil slate.

TABLE 13 CRUDE OIL PRICES
(Canadian Dollars Per Cubic Metre, Unless Otherwise Noted)

	1981	1982	1985	1990	1995
Arabian Light FOB Persian Gulf ($U.S./B)	32.33	34.00	29.87	39.97	56.06
Average Canadian CIF Import ($U.S./B)	35.97	33.52	31.30	41.26	53.04
($/m^3$)	271.29	260.09	243.05	320.41	411.87
Montreal Blended Price	173.29	205.33	230.78	315.70	415.64
Average Refinery Gate Price					
British Columbia	172.94	209.24	229.27	311.29	412.33
Prairie Provinces	168.32	203.99	222.04	302.32	401.53
Ontario	173.38	209.97	229.76	311.61	408.86
Quebec	174.83	208.84	229.37	309.49	406.08
Atlantic Provinces	173.29	205.33	222.51	301.61	404.23

8.2 Product Pricing

As stated previously, the price of refined petroleum products are determined from realization ratios which relate average crude acquisition cost and gross margin (which includes operating costs and net margin) to product prices. Appendix F shows these pricing components and a summary of historical and forecast diesel, LFO and HFO prices for each region.

Strong markets for diesel fuel are expected in all regions and it is anticipated that diesel prices will approach gasoline prices over time. Winter diesel fuel prices are expected to be 20-25% higher than crude oil cost depending on the region. Summer diesel prices are approximately 98% of winter diesel prices.

LFO will continue to be priced lower than diesel fuel throughout the forecast period. While future diesel fuel prices will be determined in a growth market, LFO has traditionally been used in the space heating market where there is strong competition from natural gas and electricity. Future LFO demand will be further eroded by competition from these fuels resulting in a widening of the differentials between diesel fuel and diesel prices. Although the LFO price is currently near the price of summer diesel in coastal regions, the LFO differential below winter diesel could be 10-15% by 1995 depending on the region (i.e. 10-15% above crude oil).

Historically, HFO has been a much lower priced fuel than diesel fuel and LFO. Future HFO prices will be influenced by imported HFO prices, the overall HFO supply/demand balance, and competition from natural gas and electricity. In all regions except the Atlantic Provinces, HFO prices are expected to range between 74% and 80% of the average crude cost. The higher level is expected in the initial years when HFO will be in shorter supply. In the Atlantic Provinces, HFO prices are expected to remain at current levels relative to crude oil (92%) in the short-term, but to become equivalent to the natural gas price when natural gas becomes available.

Table 14 provides regional summary of historical and forecast prices for diesel fuel, LFO, HFO, and HFO/LFO blends relative to crude oil.

TABLE 14 FUEL OIL PRICING
(Percent of Crude Oil Price, Volume Basis)

	1982	1995
Diesel Fuel (Winter Grade)	117-124	120-126
LFO	110-121	110-115
HFO	73-92	74-80
Blends		
10% HFO/90% LFO	106-118	106-112
30% HFO/70% LFO	99-112	99-105

9. RAILWAY FUEL

The demand for railway fuel was given in Table 3. By 1985, demand is expected to return to the 1981 level of 6.5 $10^3m^3/d$ across Canada and increase to 8.1 $10^3m^3/d$ by 1995. As shown in Table 15, this represents an increase as a percent of total crude throughput as well. Although road use of diesel fuel is expected to increase faster, LFO will decrease, as shown in Figure 4. Thus railway diesel should remain at about the same proportion of all middle distillate production throughout the forecast period. These relationships are demonstrated in Figure 4.

Railway locomotives are now operating commercially on low cetane fuels, (low 30's) which are essentially standard furnace fuels. Product specifications for diesel fuels and other fuel oils are given in Appendix B. In the Prairies, the railways have used about 800 cubic metres per day (m^3/d) low cetane diesel fuel from the Suncor tar sands plant for many years. With a price differential between diesel fuel and LFO, the capability for furnace fuel should be advantageous to the railways, and also to refiners who are facing a declining LFO market. The capability for using low cetane fuels may be especially important in the Prairies in the long run to avoid product imbalances, or installation of costly new units.

The railways have offered to accept higher end point fuel on a year round basis. If refiners can recover this material for the diesel pool, it could also assist in meeting the overall product slate. However, it would represent a new product, and would require its own storage and handling systems.

The railways are investigating the use of bunker blends in locomotives. Test work has been done on: (a) EMD and GE engines at South West Research Institute (SWRI) at San Antonio, Texas, sponsored by the Association of American Railroads (AAR), and (b) a Bombardier engine at Montreal, sponsored in part by the Department of National Defence. In addition CN Rail is testing both mainline and switcher units around Toronto and Fort Erie, Ontario. Initial tests were with 30% bunker, but blends are now down to 10% bunker. The current blend is similar to a No. 4 (ASTM) fuel oil (see Appendix B). Locomotive engines idle a great deal (up to 72 hours at one time); while idling they burn inefficiently and deposit carbonaceous material in the exhaust stack and turbocharger (if any). When the engine returns to high load, stack fires and turbocharger explosions have occurred.

Clearly there is a price incentive to use a bunker blend, since the HFO price is estimated to be about two-thirds that of furnace fuel price. The 10% bunker blend could result in a cost saving of 3-4% compared with

furnace oil. However, a 10% bunker blend for non marine use could represent a new product for most refiners. They may not have storage and handling facilities for such a product. Thus facility modifications might be needed depending on the refinery. Some refiners may have spare tankage and handling systems which could be utilized to handle such a product. Refiners are trying to minimize inventories. With demand low for products such as LFO, surplus equipment might be readily converted to a new service. Alternatively, the railways could consider receiving both HFO and LFO, and installing with their own blending facilities at major terminals. CN Marine has installed bunker blending facilities at Port-aux Basques, Newfoundland, and receive both HFO and LFO components. The costs of storage and handling should be evaluated against potential savings.

In the Prairie Provinces, the use of 10% bunker blend would represent about 350 m^3/d of HFO and add almost 50% to the HFO market since this market is limited. Some Prairie refiners export HFO from the region and could easily satisfy this volume. Across the country, the extra HFO volumes for railway fuel blending could be easily produced.

The use of bunker introduces the carbonaceous deposit problems mentioned. Since this problem is mainly due to idling, the idling operation itself limits greater savings available from higher percentage bunker blends. Idling is needed to keep the units warm (above freezing). More locomotive units are being shutdown in summer but heating is necessary in winter. Idling efficiency can be improved (and deposits reduced) through improved heat retention and/or preheat. Preheat methods could include staged fuel injection and/or glow plugs.

A dual fuel system has been considered cumbersome because of duplicate systems, and potential operating problems. However, the potential savings from idling on distillate (low consumption) and operating at heavy load on the bunker blend (say 30%) could be around 10% of fuel costs. Many ships have dual fuel systems with onboard blending for auxilliary engines.

Alternatively, the application of an auxilliary heater fuelled by distillate or bunker could be considered to keep the locomotive engine warm when it is shutdown. This would protect the unit from freezing and allow easy startup on distillate with normal operation on bunker blend. It could also conserve fuel by eliminating idling.

The use of HFO could introduce new fuel quality problems since many crude oil and refinery contaminants concentrate in the bottoms which are used in HFO. This could lead to increased maintenance costs, and perhaps require changes to engine design or materials. Sulphur content will be higher, requiring higher base lube oils, and perhaps improved metallurgy. Metals such as vanadium concentrate in HFO and can cause valve corrosion problems; vanadium is especially prevalent in some South American and Mexican heavy crude oils which are used in eastern Canada. Catalyst fines can accumulate in HFO and cause injector wear problems, since filtration of smaller than 5 micron material is difficult.

Some crudes and cracked stocks have high asphaltene content. When HFO with high asphaltene content is mixed with paraffins distillate, asphaltene precipitation can occur. Precautions are needed in selecting blend components to avoid this. This is one argument in favour of purchasing the desired blend from the refiner, rather than purchasing components and making the blends.

Railway operators should discuss HFO quality with refiners to ensure that future quality will be acceptable. Many refiners could probably protect diesel engine operators by isolating refinery streams such as cracker bottoms (catalyst fines and asphaltenes) and visbreaker bottoms (asphaltenes) for use as fuel within the refinery, or for sale as industrial or boiler fuel.

Railways have other fuel alternatives to consider for the long-term, such as methanol, compressed natural gas, coal and electricity. These are outside the scope of this study.

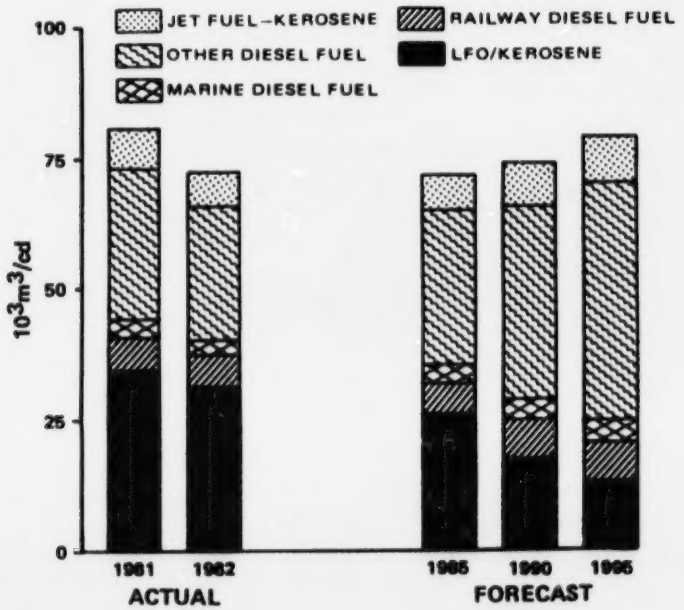

FIGURE 4 MIDDLE DISTILLATE DEMAND IN CANADA

T A B L E 15 DEMAND FOR RAILWAY DIESEL FUEL
(Percent)

	1981	1982	Base Case 1985	1990	1995
British Columbia and Territories					
% Diesel Production(1)	12.5	12.5	13.0	13.8	15.3
% Distillate Production(2)	8.2	8.4	8.8	10.0	11.3
% Crude Demand(3)	2.9	2.9	3.0	3.9	4.3
Prairie Provinces					
% Diesel Production(1)	19.8	19.4	18.8	17.9	15.5
% Distillate Production(2)	15.5	14.8	15.5	15.3	13.6
% Crude Demand(3)	4.9	4.8	5.4	6.0	6.0
Ontario					
% Diesel Production(1)	22.0	21.8	22.1	16.4	14.0
% Distillate Production(2)	8.5	9.2	9.8	9.5	9.1
% Crude Demand(3)	2.2	2.4	2.5	3.1	3.3
Quebec					
% Diesel Production(1)	10.2	10.7	16.0	17.0	15.3
% Distillate Production(2)	3.5	3.2	5.9	9.0	9.2
% Crude Demand(3)	1.1	1.0	1.7	2.3	2.5
Atlantic Provinces					
% Diesel Production(1)	12.2	13.7	8.3	7.0	6.5
% Distillate Production(2)	2.5	3.3	3.1	3.2	3.5
% Crude Demand(3)	1.0	1.3	1.1	1.4	1.6

Notes: (1) Railway demand, (Table 3) as a percent of total diesel fuel supply (Appendix A).
(2) Railway demand as a percent of total middle distillate supply, including jet fuel-kerosene, stove oil/kerosene, diesel fuel and LFO.
(3) Railway demand as a percent of crude demand (Table 5).

10. MARINE FUEL

The demand for marine fuels, both diesel and bunker, was given in Table 3. Both are expected to experience modest growth over the forecast period. Foreign ships consume more than 20% of marine diesel fuel and more than 30% of bunker fuel. Therefore, demand is partly dependent of international trade, and competitive pricing. During 1983, increased provincial taxes in British Columbia resulted in a decrease in purchases of bunker fuel by foreign ships in Vancouver in favour of the Seattle area.

Table 16 indicates that marine diesel fuel will increase as a percent of crude, and as a percent of total middle distillate. It will decline in most cases in proportion to road diesel use as demonstrated in Figure 4. If some marine diesels can tolerate furnace oil quality fuel, this market could help to offset part of the expected decline in the LFO heating market.

Table 17 shows that marine bunker demand will rise as a proportion of refinery crude throughput, and especially as a percent of total HFO production. Marine bunker sales in British Columbia have represented a high proportion (more than 60%) of HFO production. In the Atlantic region, marine bunker was 7% of HFO production in 1982, but could reach 42% by 1995. Marine bunker demand and HFO demand across Canada are demonstrated in Figure 5.

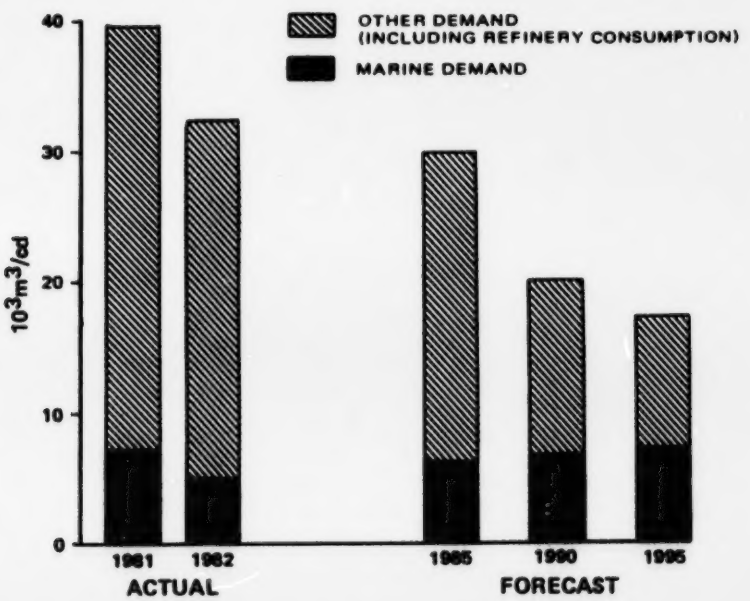

FIGURE 5 HFO DEMAND IN CANADA

T A B L E 16 DEMAND FOR MARINE DIESEL FUEL
(Percent)

			Base Case		
	1981	1982	1985	1990	1995
British Columbia and Territories					
% Diesel Production(1)	15.9	15.0	18.1	15.1	16.1
% Distillate Production(2)	10.3	10.2	12.2	10.9	11.9
% Crude Demand(3)	3.7	3.5	4.2	4.2	4.5
Ontario					
% Diesel Production(1)	5.4	4.9	6.0	4.1	3.5
% Distillate Production(2)	2.1	2.1	2.7	2.4	2.2
% Crude Demand(3)	.5	.5	.7	.8	.8
Quebec					
% Diesel Production(1)	8.2	9.3	15.2	13.9	13.6
% Distillate Production(2)	2.8	2.7	5.7	7.3	8.2
% Crude Demand(3)	.9	.9	1.6	1.9	2.2
Atlantic Provinces					
% Diesel Production(1)	33.7	37.7	23.1	21.3	20.0
% Distillate Production(2)	6.9	9.0	8.6	9.7	10.8
% Crude Demand(3)	2.7	3.5	3.1	4.4	5.0

Notes: (1) Marine diesel fuel demand (Table 3) as a percent of total diesel fuel supply (Appendix A).
(2) Marine diesel fuel demand as a percent of total middle distillate supply, including jet fuel-kerosene, stove oil/kerosene, diesel fuel distillate.
(3) Marine diesel fuel demand as a percent of crude demand (Table 5).

TABLE 17 DEMAND FOR MARINE BUNKER FUEL
(Percent)

			Base Case		
	1981	1982	1985	1990	1995
British Columbia and Territories					
% HFO Production(1)	72.5	63.2	47.0	62.6	67.2
% HFO Crude Demand(2)	7.5	6.3	7.0	7.4	8.2
Ontario					
% HFO Production(1)	7.5	6.6	13.7	21.7	31.0
% HFO Crude Demand(2)	1.2	.9	1.4	1.6	1.8
Quebec					
% HFO Production(1)	16.1	17.5	24.3	31.2	38.6
% HFO Crude Demand(2)	3.5	3.4	5.3	6.5	7.5
Atlantic Provinces					
% HFO Production(1)	16.0	7.3	8.4	33.2	42.3
% HFO Crude Demand(2)	3.5	1.5	2.3	3.4	4.1

Notes: (1) Marine bunker demand (Table 3), as a percent of total HFO required production (Appendix A).
(2) Marine bunker demand, as a percent of crude demand (Table 5).

Fuel requirements (volume and quality) are varied among marine vessels. There are many different classes, sizes and services for these vessels, including ocean-going freighters and tankers, lakers, ferries, tugs, supply boats, navy, coast guard, and various fishing vessels. These vessels have different engine performance and horsepower requirements. These factors in part determine engine selection which affects fuel selection. Marine driver systems include diesel engines, diesel fired gas turbines and bunker fired boilers with steam turbines. Turbines are decreasing in importance because of the better efficiencies available from the diesel engines. In general, diesel engines may be classified as high, medium or low speed, and each has different fuel requirements and capabilities.

High speed engines (1,200-1,800 rpm) often have horsepower rating below 1,500. These engines use clean distillate diesel fuel, referred to as gas oil in the marine industry. Applications include fishing boats, small tugs, some ferries, and the auxilliary engines for hotel services (heat and electricity) on some larger vessels.

Medium speed engines (300-1,200 rpm) with horsepower in the 1,000-6,000 range commonly use gas oil or marine diesel fuel which can include up to 10% marine bunker because of contamination in marine storage and loading systems. Applications include ferries, tugs, supply vessels, auxilliary engines, some lakers, and coastal freighters. Navy and coast guard vessels in this size category normally use gas oil.

Low speed engines (below 300 rpm) are the main drive units on most overseas vessels and lakers. They are generally more than 5,000 horsepower, and use marine bunker fuel, blended to required viscosity specifications. Some low speed engines such as ferries use diesel fuel for reliability. Large navy and coast guard units use gas oil.

The high speed marine engines are not dissimilar from road diesels, and many are produced in North America by manufacturers such as Caterpillar and Cummins. These engines are probably confined to using current quality gas oil.

Some medium speed engines are manufactured in North America by General Motors (EMD), and a few by Bombardier in Canada. Most are manufactured in Europe. These have potential to use fuels which have a lower cetane number than gas oil. Use of conventional furnace oil could save operators 10-15% on fuel costs relative to gas oil. This fuel should be readily available at refinery docks, and major product terminals, although small outlets might require modifications or new facilities.

Some marine operators have reported trying low cetane fuel, but encountered valve wear problems. Since marine specifications allow higher end point material, this could likely be overcome with careful attention to fuel and lubricant specifications. The railway locomotive engines are successfully using low cetane distillate in commercial operations.

Operators of medium speed engines have potential to reduce fuel costs further by using bunker blends with higher HFO concentration. Most refiners have bunker blenders at their docks.

Most slow speed engines are manufactured in Europe. Operators of large slow speed engines can use heavier bunker blends. Most commercial operators specify a maximum viscosity of 1,500-3,500 Redwood Seconds at 38°C (360-850 cst). Some operators prefer viscosity as low as 80 cst. Manfacturers now have designs for fuel with viscosity up to 6,000 Redwood Seconds (1,450 cst). Viscosity is controlled by refiners by blending HFO with lighter cutter stock which has higher value. The price of the blend is based on the proportion of each component.

At present, many marine operators purchase fuel on the spot market; they do not have contracts and they do not have specifications. Therefore they have no control over the quality of the fuel they receive. Even operators who do have contracts generally specify only viscosity. They sometimes have operating or maintenance problems because of contaminants in fuel. Catalyst fines cause injector wear and/or filter plugging. Vanadium causes corrosion of valves at current design temperatures. Excess asphaltenes cause fouling in the system; when paraffinic fuels are mixed in tanks or blended onboard ship, incompatibility can occur in which asphaltenes precipitate and plug the fuel system. As heavy fuel production decreases in refineries, the concentration of contaminants is expected to increase, and thus the likelihood of fuel related problems.

The CGSB Middle Distillate Subcommittee is established to recommend suitable specifications for fuel oil products including marine fuels. It has recently developed new marine fuel standards which should be published early in 1984. The subcommittee is made up of representatives of government, refining industry, engine manufacturers, and consumers. However, there is not a representative of the merchant marine industry. This subcommittee has also worked with the Canadian Advisory Committee to the International Standards Organization (ISO) in the development of an international marine fuel standard (Appendix B), originated by the Institute of Marine Engineers in Great Britain. These committees provide a forum to present problems, and understand those of others.

With the prospect for HFO quality to deteriorate, marine operators should discuss the problems with refiners to ensure that fuel quality requirements and availability are compatible. The changes needed by refiners or ship operators should be identified, and the costs (if any) defined. For instance, some refiners may be able to isolate poor quality streams such as cracker bottoms to use as internal plant fuel or to sell as industrial fuel oil.

Marine operators need to agree with refiners on reasonable specifications which protect engines, do not introduce excess costs, and are controllable. Quality control can then be introduced. Many tests are sophisticated analytical procedures. Some ship operators now air freight

samples to Europe (Norway or the Netherlands) for analysis, but the ship is fuelled and out of port by the time results are available. Operators need some simple, inexpensive onboard tests available. If complex procedures are required, facilities which can provide results may be needed in Canada.

Since marine operators usually know in advance where and when they will take on fuel, they could have samples picked up in advance from bonded tanks. Alternately, operators could operate their own fuelling facilities. This has application in ferry operations where routes are fixed. CN Marine now receives bulk deliveries of HFO and diesel fuel for storage, blending and fuelling.

Long-term, other fuel options may be available for marine application. Examples include nuclear propulsion for very large loads, fluidized bed coal combustion, methanol and liquefied natural gas (LNG) boil-off. These are outside the scope of this work.

11. CONCLUSIONS

From this analysis, a number of conclusions can be made. Many of them have direct implications to railway and marine fuel users.

1. Diesel fuel demand is expected to increase in all regions of the country throughout the forecast period to 1995. HFO demand will decline except for use as marine bunker fuel.

2. Although refineries have been closing down in recent years because of a decline in sales, there will be sufficient capacity available to produce all of the refined products which will be needed.

3. Marine bunker could be in tight supply until 1990. However, refiners should have the capability to maintain HFO supply within demand.

4. The overall refining industry in each region of Canada should be capable of producing all of the anticipated diesel fuel and marine fuel requirements with current specifications although some regional imbalances may occur. Some individual refineries may have difficulty meeting diesel demand, particularly in winter when gasoline demand is low.

5. As demand for LFO decreases, the actual cetane number of diesel fuel will fall and more closely approach minimum specifications. Given a strong demand for diesel fuel, specific refineries could have difficulty satisfying product demand at current specifications because of processing or market constraints. Transport fuel users who can tolerate lower specification fuels can alleviate potential supply problems.

6. The suitability of cetane number for measuring diesel fuel quality and the use of this test procedure for quality control are questionable. A more precise means of establishing quality of diesel fuels could become essential in order to provide confidence that the fuels will satisfy engine requirements. Current development in this area should be continued.

7. Diesel fuel prices vary seasonally because of quality, but are expected to be 20-25% over crude oil. LFO prices are expected to be 10-15% above crude oil. HFO prices are expected to be 74-80% of crude oil, except in the Atlantic region where they could remain at more than 90% of crude oil until natural gas becomes available.

8. Railways are investigating the use of blends of 10% HFO with diesel fuel. Special systems may be required by refiners or the railway operators themselves to handle this new product. Although any such changes represent additional costs, fuel savings could still be 3-4% of the cost of diesel fuel. Additional maintenance costs may be incurred.

   In the Prairie region, a 10% HFO blend for railway fuel could increase the HFO market by almost 50%.

9. Although the railway industry has taken steps to use lower cetane fuel commercially, marine operators using diesel fuel or gas oil in medium speed engines have not taken similar steps. This represents an opportunity for them to reduce fuel costs.

10. Some marine operators which are now using diesel fuel in medium speed engines may have an opportunity to reduce costs by receiving a bunker blend of 10% HFO or higher using existing dock-side bunker blending facilties.

11. Because of the temperate environment, coastal marine operators have an opportunity in the winter to accept diesel fuel with higher pour point than land users. This outlet may become more important for refineries as the total demand for diesel fuel increases in these regions. It may also provide a small saving to marine operators.

12. Commercial mariners have not participated directly in establishing marine fuel standards. They are not represented on the CGSB or ISO, both of which are currently involved in developing new marine fuel standards.

13. Marine operators have had operating problems due to contaminants and incompatibility of fuels. Most marine operators do not have fuel specifications, and so cannot control fuel quality. On the other hand, stringent specifications imposed on refiners may require additional handling or even processing steps which could result in additional costs.

14. There are currently not any simple and rapid analytical procedures available for all the marine fuel properties of interest. Some samples are now air freighted to Europe for results within days. Mariners need to ensure satisfactory fuel quality before they leave port.

15. In eastern Canada (Ontario, Quebec, and the Atlantic Provinces), marine bunker fuel will represent an increasing proportion of HFO production throughout the forecast, reaching 30-40% of HFO production by 1995, instead of 7-17% at present. Marine operators could have a stronger position in determining bunker prices and specifications.

16. The quality of HFO available is expected to gradually deteriorate over the next 10-15 years as total HFO production falls, and contaminants concentrate. These contaminants include catalyst fines, metals (e.g. vanadium), and asphaltenes. These could increase operating and maintenance problems for transport users of HFO.

12. RECOMMENDATIONS

Based on the analyses undertaken in this assignment, Hycarb believes the following recommendations are important to railway and marine fuel users:

1. Operators, refiners, and engine manufacturers should seek to match fuel quality and engine requirements, and use lower quality fuels where possible. One excellent example is the use of conventional furnace fuel in railway locomotives.

2. Marine operators should investigate the opportunity for the use of commercially available furnace fuel in medium speed engines. They should also investigate possible fuel changes, such as using high pour point fuels year round, and higher boiling point fuels.

3. Railway operators should continue the laboratory and commercial tests on diesel/bunker blends. However, they should also investigate the systems which are available and/or required to provide this fuel commercially, the maintenance requirements, and establish appropriate cost/benefit relationships.

4. Railways should investigate means of increasing use of heavy fuel by utilizing dual fuel systems, with the lighter fuel used under idling conditions, and a HFO blend under load conditions. Improved preheat, and engine materials should also be considered. Alternatively, auxilliary heating systems could be utilized to avoid idling, and conserve fuel.

5. Marine operators of medium/low speed diesel engines should investigate the use of the heavier fuels because of potential cost savings on cutter stock. This should recognize the fuel needs of auxilliary engines as well as main drives.

6. Marine operators should become more actively involved in determining reasonable fuel specifications in order to protect their equipment in the future. They should participate in committees such as CGSB and ISO.

7. Marine operators should investigate with refiners means of minimizing contaminants in bunker fuel, e.g. isolation of cracker and visbreaker bottoms streams within refineries to use in refinery heaters, or sell as industrial fuels rather than diesel engine fuel. Also, engine manufacturers should investigate improved filtration systems and/or injector systems to tolerate catalyst fines.

8. Contaminant levels in HFO could increase because of increased use of heavy crudes in refineries. For example, vanadium in HFO could increase in Quebec and the Atlantic Provinces because of Mexican or Venezuelan crudes refined there. Engine manufacturers should further investigate improved design or metallurgy to tolerate such impurities.

9. Marine operators should also investigate procedures to improve quality control, such as sampling in advance of receipt and to carry out adequate analyses in time to ensure satisfactory fuel quality before leaving port. Preferrably, some tests should be simple, inexpensive, and carried out onboard. Since many tests involve sophisticated and expensive equipment, consideration should be given to a test laboratory in Canada to serve local needs in minimum time. Alternatively, refiners could be requested to perform the necessary tests.

10. The ongoing review of the applicability of ASTM D613 cetane engine test should be continued in light of various types of diesel fuels, including cracked stocks, and in light of the need for tight quality control in the future. The suitability of alternative ignition quality and/or combustion quality test procedures may have to be investigated further.

GLOSSARY OF TERMS

UNITS

°API:	Gravity, degress API
B:	Barrel
m^3/d:	Cubic metres per day
g/l:	Grams per litre
HP:	Horsepower
$10^3m^3/cd$:	Thousands of cubic metres per calender day
rpm:	Revolutions per minute
wt.% S:	Weight percent sulphur

ORGANIZATIONS

API:	American Petroleum Institute
ASME:	American Society of Mechanical Engineers
ASTM:	American Society for Testing Materials
AAR:	Association of American Railways
APPL:	Alberta Product Pipeline Ltd.
CGSB:	Canadian Government Specification Board
CRC:	Co-Ordinating Research Council
ERCB:	Energy Resources Conservation Board
Esso:	Esso Petroleum Canada
Gulf:	Gulf Canada Limited
Hycarb:	Hycarb Engineering Ltd.
IPL:	Interprovincial PipeLine Limited
Irving:	Irving Oil Ltd.
ISO:	International Standards Organization
NEB:	National Energy Board
Petrosar:	Petrosar Limited
Shell:	Shell Canada Limited
Suncor:	Suncor Inc.
SWRI:	South West Research Institute
TDC:	Transportation Development Centre
Texaco:	Texaco Canada Inc.
TMPL:	Trans Mountain Pipe Line Company Ltd.
TNPI:	Trans-Northern Pipelines Inc.
Turbo:	Turbo Resources Limited
Ultramar:	Ultramar Canada Inc.

TERMS

Bunker:	Marine residual fuel blended with distillate fuel to control viscosity.

Cetane: A measure of the ignition delay characteristics of a diesel fuel. Typically specified by the engine manufacturer to be a minimum value.

- Cetane number: The cetane of a diesel fuel as measured in a laboratory test engine.
- Cetane index: A calculated number, based (currently) on the diesel mid boiling point and API gravity. Correlates typically to two or three numbers higher than the measured cetane number. A new "Canadian cetane index", based on gravity, aniline point, and viscosity, is more applicable to synthetic and cracked material.

Cloud Point: The temperature at which wax starts to crystallize out of solution. Typically 10°F higher than the pour point.

Diesel Fuel: Distillate fuel for use in diesel engines. Road diesel fuel cetane number exceeds 40. In the marine industry, up to 10% residual fuel is allowed.

Distillates: Defined as that fraction of the crude oil barrel (or that fraction of a cracking unit product) which boils typically in the range of 177-343°C. Distillate can be subdivided into various cuts.

i) 177-232°C (light kerosene) used in kerosene jet fuel, specialty products and arctic diesel.
ii) 177-288°C (wide cut kerosene or stove oil) used as low pour home heating oil, and low pour diesel.
iii) 232-343°C (atmospheric gas oil) used in high pour diesels and home heating oil. (The gas oil from a catalytic cracking unit is limited in diesel blends to approximately 20% by volume as limited by cetane.)

Engine Speed: Marine - Low, less than 300 rpm
- Medium, 300-1,200 rpm
- High, 1,200-1,800 rpm

Railway - Medium (900-1,200 rpm)

EPA: Energy Pricing Agreement

FCC: Fluid catalytic cracking

Gas Oil: Marine terminology for road diesel fuel quality distillate.

HFO: Heavy fuel oil

LFO: Light fuel oil

LP: Linear program

LNG: Liquefied natural gas

Pour Point: That temperature at which the oil no longer flows.

R&D: Research and Development

TEL: Tetra-ethyl-lead

Utilization: Refinery crude throughput divided by effective crude capacity.

APPENDIX "A"

PRODUCT SUPPLY/DEMAND

TABLE A-1

NET TRANSFERS OF PRODUCTS BETWEEN ADJACENT REGIONS OF CANADA
(Thousands of Cubic Metres Per Calendar Day)

	Prairie Provinces To British Columbia and Territories				Prairie Provinces to Ontario				Quebec to Ontario				Quebec to Atlantic Provinces			
	1981[1]	1982[1]	Base Case[2] 1985-1995	High Demand Case[2] 1995	1981[1]	1982[1]	Base Case[2] 1985-1995	High Demand Case[2] 1995	1981[1]	1982[1]	Base Case[2] 1985-1995	High Demand Case[2] 1995	1981[1]	1982[1]	Base Case[2] 1985-1995	High Demand Case[2] 1995
Gasoline	1.36	.84	1.70	4.00	.45	.34	.45	.45	1.75	2.23	-1.49	-.66	-	.05	-	-
Jet Fuel	.18	.21	.20	.20	-	-.07	-	-	.34	.30	-.03	-	.23	.30	-	-
Diesel Fuel	1.10	1.12	1.62[3]	6.44	.07	.07	.29	.29	-	.34	-.77	-	.50	.74	-	-
LFO/Kerosene	.22	.22	.24	.24	-	-.06	.02	.02	.12	.06	-1.49	-.50	.32	.41	-	-
HFO	1.09	.57	-	.30	.44	.17	.30	-	-	-.53	-	-	.51	.42	-	-
Asphalt	.13	.04	.13	.13	.01	-	.01	.01	.77	.95	.80	1.70	.10	.07	-	-
Other[4]	.57	.46	.67	.67	-	-.31	-.09	-.09	-.28	.16	-.14	-.15	-	.28	.07[5]	.09[5]
Total	4.65	3.46	4.56	11.98	.97	.14	.98	.68	2.70	3.51	-3.12	.99	1.66	2.27	.07	.09

Notes: (1) Source: Statistics Canada Catalogue 45-004.
(2) Hycarb forecast.
(3) Base Case: 1985, 1.62
1990, 1.62
1995, 3.12
(4) Includes petrochemical feedstocks, specialty naphthas, lube oils and greases, petroleum coke and other.
(5) Base Case: 1985, .07 High Demand Case: 1985, .09
1990, .09 1990, .12
1995, .12 1995, .15

TABLE A-2

PRODUCT DEMAND AND SUPPLY - BRITISH COLUMBIA AND TERRITORIES
(Thousands of Cubic Metres Per Calendar Day)

	1981(1)		1982(1)		Base Case(2) 1985		1990		1995		High Demand Case(3) 1995	
	Demand	Production	Demand	Production	Demand	Production	Demand	Production	Demand	Production	Demand	Production
LPG	.57	.57	.63	.51		.39		.41		.44		.52
Petrochemical Feedstocks	.20	.19	.16	.16	.19	.19	.19	.19	.19	.19	.20	.20
Naphtha		.05		.05		.05		.05		.05		.05
Gas Oil		.00		.00		.00		.00		.00		.00
Aromatics		.14		.11		.14		.14		.14		.15
Specialty Naphthas	.07	.07	.05	.08	.07	.07	.08	.08	.08	.08	.08	.08
Aviation Gasoline	.16	.03	.11	.05	.16	.00	.16	.00	.16	.00	.16	.00
Motor Gasoline	12.26	11.33	11.30	11.32	11.14	9.59	11.31	9.76	11.30	9.75	13.52	9.69
Premium Unleaded	.82	.76	.90	.90		.77		.88		.98		.97
Regular Unleaded	2.78	2.57	2.60	2.60		2.88		3.90		4.19		4.17
Regular Leaded	8.66	8.00	7.80	7.81		5.95		4.98		4.58		4.55
Jet Fuel-Kerosene	1.00	.89	.84	.76	.93	.85	1.14	1.06	1.33	1.25	1.60	1.52
Jet Fuel-Naphtha	1.19	1.01	.91	.75	1.09	.97	1.34	1.22	1.57	1.45	1.87	1.75
Stove Oil/Kerosene	.51	.44	.54	.38	.44	.33	.39	.28	.33	.22	.36	.25
Diesel Fuel	7.18	6.23	6.60	5.86	7.08	5.48	8.77	7.17	10.49	7.39	11.74	5.32
Winter Grade	3.59	3.12	3.30	2.93		2.74		3.59		3.70		2.66
Summer Grade	3.59	3.12	3.30	2.93		2.74		3.59		3.70		2.66
LFO	2.06	2.01	1.92	1.67	1.58	1.45	1.51	1.38	1.26	1.13	1.42	1.29
HFO	4.38	2.76	3.72	2.50	3.49	3.55	2.99	3.05	3.17	3.23	4.15	3.91
High Sulphur	3.30	2.08	2.86	1.92		2.66		2.29		2.42		2.93
Low Sulphur	1.08	.68	.86	.58		.89		.76		.81		.98
Asphalt	.80	.69	.58	.56	.66	.53	.77	.64	.87	.74	1.30	1.17
Lube Oils and Greases	.31	.05	.28	.04	.33	.12	.39	.18	.45	.24	.48	.27
Other(4)	.54	.89	.13	.64		.72		.77		.83		.98
Total	31.23	27.18	27.77	25.28	27.16	24.23	29.04	26.19	31.20	26.96	36.88	26.96

Notes: (1) Source: Statistics Canada Catalogue 45-004.
(2) Hycarb forecast, "Canadian Refining Outlook to 1992" March, 1983. Developed from demand forecast based on 1982 estimate and NEB low demand growth rates from "Canadian Energy Supply and Demand: 1980-2000", June 1981.
(3) Hycarb forecast, "Canadian Refining Outlook to 1992" March, 1983. Developed from demand forecast based on 1981 actual and NEB middle demand growth rates from "Canadian Energy Supply and Demand: 1980-2000", June 1981.
(4) Includes still gas, petroleum coke, and other.

TABLE A-3

PRODUCT DEMAND AND SUPPLY - PRAIRIE PROVINCES
(Thousands of Cubic Metres Per Calendar Day)

	1981(1)		1982(1)		Base Case(2)						High Demand Case(3)	
					1985		1990		1995		1995	
	Demand	Production	Demand	Production	Demand	Production	Demand	Production	Demand	Production	Demand	Production
LPG	1.51	1.48	1.48	-.67		1.49		1.61		1.71		1.98
Petrochemical Feedstocks	.01	.01	.01	.01	.82	.82	.82	.82	.82	.82	.82	.82
Naphtha		.01		.01		.01		.01		.01		.01
Gas Oil		.00		.00		.00		.00		.00		.00
Aromatics		.00		.00		.81		.82		.82		.81
Specialty Naphthas	.08	.08	.08	.06	.09	.06	.10	.07	.10	.07	.10	.07
Aviation Gasoline	.20	.42	.17	.26	.20	.41	.20	.41	.20	.41	.20	.41
Motor Gasoline	23.63	25.13	22.52	23.83	20.79	22.73	20.20	22.14	19.12	21.06	22.99	27.23
Premium Unleaded	.83	1.00	.76	.80		1.14		1.33		1.26		1.63
Regular Unleaded	5.12	5.58	5.25	5.56		7.50		9.52		9.69		12.53
Regular Leaded	17.67	18.56	16.51	17.47		14.09		11.29		10.11		13.07
Jet Fuel-Kerosene	1.27	1.33	1.41	1.48	1.32	1.40	1.58	1.66	1.84	1.92	1.96	2.04
Jet Fuel-Naphtha	1.79	2.04	1.42	1.59	1.83	1.95	2.18	2.30	2.55	2.67	2.71	2.83
Stove Oil/Kerosene	.75	1.13	.82	1.22	.67	.81	.53	.66	.43	.57	.43	.56
Diesel Fuel	12.68	13.15	12.04	11.96	13.32	14.44	16.80	17.92	19.84	22.46	21.92	27.83
Winter Grade	7.61	7.89	7.22	7.18		8.66		10.75		13.48		16.70
Summer Grade	5.07	5.26	4.82	4.78		5.78		7.17		8.98		11.13
LFO	1.03	1.22	1.04	1.01	.75	.88	.62	.75	.51	.64	.59	.72
HFO	.42	2.55	.61	1.63	.43	.90	.33	.82	.30	.80	.35	.88
High Sulphur	.42	2.49	.50	1.34		.88		.79		.77		.85
Low Sulphur	.01	.06	.11	.29		.03		.03		.03		.03
Asphalt	2.67	2.76	2.25	2.04	2.19	2.33	2.60	2.74	2.95	3.09	4.30	4.44
Lube Oils and Greases	.70	.57	.59	.30	.70	.57	.82	.69	.95	.82	1.07	.94
Other(4)	.88	3.93	1.58	4.07		3.81		4.14		4.39		5.08
Total	47.62	55.81	46.02	48.79	43.11	52.59	46.78	56.73	49.61	61.42	57.44	75.83

Notes: (1) Source: Statistics Canada Catalogue 45-004.
(2) Hycarb forecast, "Canadian Refining Outlook to 1992" March, 1983. Developed from demand forecast based on 1982 estimate and NEB low demand growth rates from "Canadian Energy Supply and Demand: 1980-2000", June 1981.
(3) Hycarb forecast, "Canadian Refining Outlook to 1992" March, 1983. Developed from demand forecast based on 1981 actual and NEB middle demand growth rates from "Canadian Energy Supply and Demand: 1980-2000", June 1981.
(4) Includes still gas, petroleum coke, and other.

TABLE A-4

PRODUCT DEMAND AND SUPPLY - ONTARIO
(Thousands of Cubic Metres Per Calendar Day)

	1981[1]		1982[1]		Base Case[2] 1985		1990		1995		High Demand Case[3] 1995	
	Demand	Production	Demand	Production	Demand	Production	Demand	Production	Demand	Production	Demand	Production
LPG	1.46	.79	1.93	.89		.63		.59		.56		.70
Petrochemical Feedstocks	7.05	10.31	5.72	8.65	4.87	7.05	4.60	6.78	4.60	6.78	7.48	9.96
Naphtha		7.09				2.72		2.43		2.43		4.41
Gas Oil		1.41				2.43		2.43		2.43		3.45
Aromatics		1.81				1.90		1.92		1.92		2.10
Specialty Naphthas	1.02	1.75	.73	1.59	.86	1.55	1.00	1.67	1.05	1.73	1.21	1.90
Aviation Gasoline	.13	.03	.11	.03	.11	.02	.11	.02	.11	.02	.11	.02
Motor Gasoline	35.27	31.68	32.83	28.97	29.93	26.61	26.58	27.12	23.28	23.82	28.06	27.11
Premium Unleaded	3.71	3.33	3.06	2.70		2.13		2.44		2.38		2.71
Regular Unleaded	12.52	11.25	12.53	11.06		10.38		13.56		11.91		13.56
Regular Leaded	19.04	17.10	17.22	15.20		14.10		11.12		9.53		10.84
Jet Fuel-Kerosene	2.95	2.61	2.74	2.49	2.62	2.25	3.09	3.12	3.45	3.48	3.95	3.95
Jet Fuel-Naphtha	.63	.60	.59	.53	.57	.57	.68	.68	.76	.76	.87	.87
Stove Oil/Kerosene	.57	.72	.55	.17	.53	.51	.28	.36	.21	.29	.20	.18
Diesel Fuel	9.26	8.76	8.87	8.33	9.28	8.47	12.49	13.03	15.08	15.62	16.69	16.46
Winter Grade	5.56	5.26	5.32	5.00		5.08		7.82		9.37		9.88
Summer Grade	3.70	3.51	3.55	3.33		3.39		5.21		6.25		6.58
LPG	10.71	10.56	9.29	8.77	8.35	7.91	4.67	6.08	3.22	4.43	3.79	4.31
HFO	7.04	13.93	3.95	10.71	4.66	7.82	3.83	5.29	2.55	3.94	4.69	6.78
High Sulphur	2.81	3.64	1.58	2.70		2.53		2.12		1.57		2.71
Low Sulphur	4.23	10.29	2.46	8.01		5.29		3.18		2.36		4.07
Asphalt	2.09	1.23	1.83	1.19	1.88	1.07	2.14	1.33	2.33	1.52	3.18	1.47
Lube Oils and Greases	1.15	1.45	.98	1.29	1.03	1.47	1.29	1.73	1.49	1.93	1.70	2.14
Other[4]	1.16	4.06	1.07	2.83		2.90		2.72		2.60		3.22
Total	80.49	88.48	71.19	76.44	64.70	68.83	60.76	70.53	58.13	67.68	71.93	79.06

Notes: (1) Source: Statistics Canada Catalogue 45-004.
(2) Hycarb forecast, "Canadian Refining Outlook to 1992" March, 1983. Developed from demand forecast based on 1982 estimate and NEB low demand growth rates from "Canadian Energy Supply and Demand: 1980-2000", June 1981.
(3) Hycarb forecast, "Canadian Refining Outlook to 1992" March, 1983. Developed from demand forecast based on 1991 actual and NEB middle demand growth rates from "Canadian Energy Supply and Demand: 1980-2000", June 1981.
(4) Includes still gas, petroleum coke, and other.

TABLE A-5

PRODUCT DEMAND AND SUPPLY - QUEBEC
(Thousands of Cubic Metres Per Calendar Day)

	1981[1]		1982[1]		Base Case[2]						High Demand Case[3]	
					1985		1990		1995		1995	
	Demand	Production	Demand	Production	Demand	Production	Demand	Production	Demand	Production	Demand	Production
LPG	.90	1.54	1.06	1.35		.88		.76		.69		.85
Petrochemical Feedstocks	3.48	3.52	2.82	3.36	2.42	3.09	2.23	2.90	2.23	2.90	3.35	4.02
Naphtha		1.59				1.30		1.10		1.10		1.50
Gas Oil		.40				.37		.37		.37		1.06
Aromatics		1.53				1.42		1.43		1.43		1.46
Specialty Naphthas	.25	.15	.19	.10	.28	.24	.30	.26	.33	.29	.35	.31
Aviation Gasoline	.08	.20	.06	.14	.07	.11	.07	.11	.07	.11	.07	.11
Motor Gasoline	22.37	24.16	19.42	21.54	17.95	15.85	15.77	14.02	13.52	11.77	16.81	15.90
Premium Unleaded	4.37	4.72	2.82	3.13		1.90		1.26		.94		1.27
Regular Unleaded	7.13	7.70	6.38	7.08		6.34		6.31		5.41		7.31
Regular Leaded	10.87	11.74	10.22	11.34		7.61		6.45		5.41		7.31
Jet Fuel-Kerosene	1.68	2.14	1.63	2.17	1.58	1.59	1.80	1.77	1.92	1.89	2.14	2.14
Jet Fuel-Naphtha	.57	.66	.41	.43	.50	.51	.57	.57	.61	.61	.67	.67
Stove Oil/Kerosene	.82	.77	.78	.89	.54	.44	.32	.22	.24	.14	.27	.27
Diesel Fuel	7.32	7.94	5.89	6.14	5.95	5.26	6.50	5.81	7.03	6.34	8.10	8.18
Winter Grade	4.39	4.76	3.53	3.68		3.16		3.49		3.80		4.91
Summer Grade	2.93	3.18	2.36	2.46		2.10		2.32		2.54		3.27
LFO	12.03	12.54	11.03	11.54	8.21	6.83	4.64	3.24	3.55	2.17	4.21	3.72
HFO	14.11	16.31	11.81	12.88	9.83	10.96	7.93	8.90	6.64	7.52	8.90	10.00
High Sulphur	12.52	14.47	10.27	11.20		9.64		7.83		6.62		8.80
Low Sulphur	1.59	1.84	1.54	1.68		1.32		1.07		.90		1.20
Asphalt	1.69	2.89	1.49	2.72	1.56	2.36	1.66	2.46	1.74	2.54	2.23	3.93
Lube Oils and Greases	.48	.56	.40	.42	.44	.52	.50	.60	.56	.69	.64	.78
Other[4]	1.43	2.88	1.14	3.08		1.77		1.53		1.39		1.72
Total	67.21	76.24	58.13	66.76	49.07	50.41	42.29	56.30	38.44	50.46	47.74	52.61

Notes: (1) Source: Statistics Canada Catalogue 45-004.
(2) Hycarb forecast, "Canadian Refining Outlook to 1992" March, 1983. Developed from demand forecast based on 1982 estimate and NEB low demand growth rates from "Canadian Energy Supply and Demand: 1980-2000", June 1981.
(3) Hycarb forecast, "Canadian Refining Outlook to 1992" March, 1983. Developed from demand forecast based on 1981 actual and NEB middle demand growth rates from "Canadian Energy Supply and Demand: 1980-2000", June 1981.
(4) Includes still gas, petroleum coke, and other.

TABLE A-6

PRODUCT DEMAND AND SUPPLY - ATLANTIC PROVINCES
(Thousands of Cubic Metres Per Calendar Day)

	1981(1)		1982(1)		Base Case(2)						High Demand Case(3)	
					1985		1990		1995		1995	
	Demand	Production	Demand	Production	Demand	Production	Demand	Production	Demand	Production	Demand	Production
LPG	.33	.70	.29	.57		.64		.48		.45		.59
Petrochemical Feedstocks	.07	.07	.07	.07	.11	.22	.11	.22	.11	.22	.12	.23
Naphtha		.07		.07		.22		.22		.22		.23
Gas Oil		.00		.00		.00		.00		.00		.00
Aromatics		.00		.00		.00		.00		.00		.00
Specialty Naphthas	.02	.00	.02	.00	.01	.00	.01	.00	.01	.00	.02	.00
Aviation Gasoline	.03	-.01	.03	.00	.03	.03	.03	.03	.03	.03	.03	.03
Motor Gasoline	8.47	10.31	7.88	7.56	7.20	7.21	6.66	6.67	5.99	6.00	7.18	7.19
Premium Unleaded	.73	.92	.54	.52		.43		.47		.48		.58
Regular Unleaded	3.23	4.11	3.11	2.98		3.32		3.27		2.94		3.52
Regular Leaded	4.51	5.75	4.24	4.06		3.46		2.93		2.58		3.09
Jet Fuel-Kerosene	.72	.98	.64	.35	.59	.59	.70	.70	.78	.78	.88	.88
Jet Fuel-Naphtha	.44	.32	.53	.36	.23	.23	.27	.28	.31	.31	.34	.34
Stove Oil/Kerosene	.69	.53	.35	.35	.51	.51	.38	.38	.31	.31	.38	.38
Diesel Fuel	3.95	2.70	2.04	2.04	3.83	3.86	4.42	4.45	5.02	5.05	5.62	5.65
Winter Grade	2.37	1.62	2.24	1.22		2.32		2.67		3.03		3.39
Summer Grade	1.58	1.08	1.50	.82		1.54		1.78		2.02		2.26
LPO	5.43	9.02	5.32	5.78	5.39	5.40	4.22	4.23	3.19	3.20	3.57	3.58
HFO	9.60	7.55	8.54	4.67	7.44	7.86	1.89	2.20	1.64	1.94	4.56	4.94
High Sulphur	9.27	7.29	8.35	4.57		7.62		2.14		1.88		4.79
Low Sulphur	.32	.26	.19	.10		.24		.07		.06		.15
Asphalt	.61	1.59	.53	.49	.62	1.42	.71	1.51	.82	1.62	.86	1.66
Lube Oils and Greases	.18	.01	.16	.01	.18	.01	.20	.01	.23	.01	.25	.01
Other(4)	.01	1.42	.00	.60		1.23		.92		.87		1.12
Total	30.55	35.19	28.36	22.85	26.14	29.21	19.60	22.08	18.44	20.79	23.81	26.60

Notes: (1) Source: Statistics Canada Catalogue 45-004.
(2) Hycarb forecast, "Canadian Refining Outlook to 1992" March, 1983. Developed from demand forecast based on 1982 estimate and NEB low demand growth rates from "Canadian Energy Supply and Demand: 1980-2000", June 1981.
(3) Hycarb forecast, "Canadian Refining Outlook to 1992" March, 1983. Developed from demand forecast based on 1981 actual and NEB middle demand growth rates from "Canadian Energy Supply and Demand: 1980-2000", June 1981.
(4) Includes still gas, petroleum coke, and other.

APPENDIX "B"

PRODUCT SPECIFICATIONS

TABLE B-1

DIESEL ENGINE FUEL SPECIFICATIONS

	Diesel Fuel		Railway[1] Diesel Fuel	Bunker (HFO)
	Winter	Summer		
Minimum Flash, °C	40.0	40.0	40.0	60.6
Maximum Viscosity, CS at 40°C	4.1	4.1	4.5	648 (at 50°C)
Minimum Viscosity, CS at 40°C	1.3	1.4	1.6	92 (at 50°C)
Maximum Pour Pt. °C	-40	-6.9°C	(2)	-
Maximum Cloud Pt., °C	-34	(3)	(3)	-
Minimum Cetane Number	40.0	40.0	30.0	-
Maximum Sulphur, wt. %	0.5	0.7	0.5	(3)
Maximum 90% Recovered, °C	315	360	345	-

Notes: (1) CNR specification.
(2) To be reported.
(3) 2.5% Low End Design Temperature (CGSB - CAN2-3.6-M83).
(4) May be stipulated by contract or government regulation.

TABLE B-2

FUEL OIL SPECIFICATIONS(1)

FUEL OIL TYPE ASTM Number		LFO NO.2	HFO NO.4	 NO.6
Flash Point	°C, Min.	40	54	60
Sulphur, % mass	Max.	0.7	-	-
Pour Point	°C, Max.	(2)	(2)	-
Cloud Point	°C, Max.	(2)	(2)	-
Water and Sediment, % vol. or mass	Max.	0.05	0.50	2.00
Ash, % mass	Max.	-	0.10	-
Distillation: 90% recovered	°C, Max.	360	-	-
Kinematic Viscosity at 40°C, mm^2/s, (cSt)	Min.	1.6(3)	5.5	-
	Max.	3.6(4)	24.0	-
Kinematic Viscosity at 50°C, mm^2/s, (cSt)	Min.	-	-	92
	Max.	-	-	638
Density, at 15°C, kg/L	Max.	0.900	-	-
Carbon Residue, on 10% residuum, % mass	Max.	0.35	-	-

Notes: (1) From CGSB CAN2-3.2-M83.
(2) To be reported.
(3) If the cloud point is <-30°C, the minimum viscosity may be reduced to 1.3 mm^2/s.
(4) This is intended for fuels supplied to the burner at or below 5°C. Above this temperature, higher viscosity fuels may be acceptable where there is agreement.

TABLE B-3

PROPOSED MARINE FUEL STANDARDS[1]

Grade Inspection	MA		MB		MC		MD		ME		MF		MG		MH		MI		MJ	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Density at 15°C	-	-	-	0.90	-	0.920	-	0.990	-	0.990	-	0.990	-	0.990	-	0.990	-	0.990	-	-
Viscosity Kinematic cSt at 40°C	1.5	5.5	-	11.0	-	14.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Viscosity Kinematic cSt at 80°C	-	-	-	-	-	-	-	15	-	25	-	45	-	75	-	100	-	130	-	130
Flash Point PM (Closed)°C	43	-	60	-	60	-	60	-	60	-	60	-	60	-	60	-	60	-	60	-
Pour Point (Upper) °C 1 Dec.-31 March	-	-	-	0	-	0	-	24	-	30	-	30	-	30	-	30	-	30	-	30
Pour Point (Upper) °C 1 Apr.-30 Nov.	-	-	-	6	-	6	-	24	-	30	-	30	-	30	-	30	-	30	-	30
Cloud Point °C	-	-16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ramsbottom Carbon wt.%	-	0.20	-	0.25	-	2.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Conradson Carbon wt.%	-	-	-	-	-	-	-	12.0	-	14.0	-	18.0	-	22.0	-	22.0	-	22.0	-	-
Sulphur wt.%	-	1.0	-	2.0	-	2.0	-	3.5	-	4.0	-	5.0	-	5.0	-	5.0	-	5.0	-	5.0
Ash wt.%	-	0.01	-	0.01	-	0.05	-	0.10	-	0.10	-	0.15	-	0.20	-	0.20	-	0.20	-	0.20
Sediment by Extraction wt.%	-	0.01	-	0.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sediment (Total Existent)	-	-	-	-	-	(2)	-	(2)	-	(2)	-	(2)	-	(2)	-	(2)	-	(2)	-	(2)
Water Volume %	-	0.05	-	0.25	-	0.30	-	0.50	-	0.80	-	1.0	-	1.0	-	1.0	-	1.0	-	1.0
Octane Index	45	-	35	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ignition Quality	-	-	-	-	(2)	-	(2)	-	(2)	-	(2)	-	(2)	-	(2)	-	(2)	-	-	-
Metal Contents, ppm Vanadium	-	-	-	-	-	100	-	250	-	350	-	500	-	600	-	600	-	600	-	600
Aluminum[3]	-	-	-	-	-	-	-	30	-	30	-	30	-	30	-	30	-	30	-	-

Notes: (1) Source: Institute of Marine Engineers, Trans. I Mar E(TM), 1981, Vol. 93, Paper 9.
(2) Considered important but currently no standard test method available.
(3) An acceptable test method has to be agreed.

APPENDIX "C"

CRUDE SUPPLY/ALLOCATION

TABLE C-1

CANADIAN REFINERY FEEDSTOCK SUPPLIES
BASE CASE
(Thousands of Cubic Metres Per Calendar Day)

	1981(1)	1982(1)	1985	1990	1995
Light Crude Oil					
Old Light Oil	171.3	156.4	93.2	51.3	29.6
Unsegregated Diluent	2.9	2.3	4.2	2.8	2.4
Subtotal	174.2	158.7	97.4	54.1	31.4
New Light Oil	2.7	6.3	42.0	53.1	57.3
Total Light Crude Oil	176.9	165.0	139.4	107.2	88.7
Heavy Crude Oil					
Old Heavy Oil	31.4	29.5	14.9	0.6	-
New Heavy Oil	4.5	8.1	23.5	30.4	34.2
Bitumen	0.6	1.5	2.2	1.8	1.7
Diluent	2.1	2.7	4.0	3.0	3.1
Total Heavy Crude Oil	38.6	41.8	44.6	35.8	39.0
Bitumen					
Refinery Feed	1.0	0.8	1.0	1.7	2.0
Export Volume	0.0	0.0	1.8	1.5	1.3
Diluent-Export	0.0	0.0	0.6	0.5	0.5
Total Bitumen	1.0	0.8	3.4	3.7	3.8
Pentanes Plus					
Total	15.2	17.0	20.0	15.0	14.0
Less:					
Unsegregated	2.9	2.3	4.2	2.8	1.8
Heavy Crude Diluent	2.1	2.6	4.0	3.0	3.1
Bitumen Diluent	0.0	0.1	0.6	0.5	0.5
Segregated Pentanes Plus	10.2	12.0	11.2	8.7	8.6
Synthetic					
Oil Sands	16.2	21.2	28.0	29.0	29.0
Upgraded Heavy	-	-	-	7.0	7.0
Total Synthetic	16.2	21.2	28.0	36.0	36.0
Frontier	-	-	-	14.3	56.0
Total Crude Oil and Equivalent	242.9	240.8	226.6	205.7	232.1

Note: (1) Productive capacity, except synthetic crude.

TABLE C-2

ALLOCATION OF CRUDE OIL IN CANADA (1)
BASE CASE
(Thousands of Cubic Metres Per Day)

Year	Region	Total Demand	Light	Pentanes Plus	Medium Heavy	Bitumen	Synthetic	Frontier	Canada Supply	Imported Crude: By Exchanges	Imported Crude: Net Imports
1981											
	Demand										
	British Columbia	26.8	24.9	1.0	-	.1	.8	-	26.8		-
	Prairie Provinces	53.1	39.7	4.0	4.4	.9	4.1	-	53.1		-
	Ontario	87.9	64.3	4.5	7.5	-	5.9	-	82.2	5.7	-
	Quebec	75.4	21.9	.9	6.9	-	4.6	-	34.3	3.3	37.8
	Atlantic	34.2	-	-	-	-	-	-	-	-	34.2
	Subtotal	277.4	150.8	10.4	18.8	1.0	15.4	-	196.4	9.0	72.0
	Exports	14.3	-	-	13.5	-	.8		14.3	-	-
	Exchanges	-	9.0	-	-	-	-	-	9.0	(9.0)	-
	Total	291.7	159.8	10.4	32.3	1.0	16.2	-	219.7	-	72.0
1982											
	British Columbia	25.0	22.6	.8	-	-	1.6	-	25.0	-	-
	Prairie Provinces	48.1	32.1	6.6	3.0	.8	5.6	-	48.1	-	-
	Ontario	75.7	54.5	3.6	6.6	-	4.6	-	69.3	6.4	-
	Quebec	65.9	26.7	.9	3.5	-	4.7	-	35.8	2.8	27.3
	Atlantic	22.2	4.8	-	-	-	-	-	4.8	-	17.4
	Subtotal	236.8	140.7	11.9	13.1	.8	16.5	-	183.0	9.2	44.7
	Exports	23.6	-	1.0	17.9	-	4.7	-	23.6	-	-
	Exchanges	-	9.2	-	-	-	-	-	9.2	(9.2)	-
	Total	260.4	149.9	12.9	31.0	.8	21.2	-	215.8	0.0	44.7
1985											
	Supply		139.4	11.2	44.6	3.4	28.0	-	226.6		
	Allocate										
	British Columbia	23.8	20.5	1.0	-	-	2.3	-	23.8	-	-
	Prairie Provinces	49.8	30.1	4.9	3.6	1.0	10.2	-	49.8	-	-
	Ontario	73.9	46.6	4.3	7.5	-	7.5	-	65.9	8.0	-
	Quebec	50.1	11.2	1.0	2.6	-	8.0	-	22.8	15.0	12.3
	Atlantic	28.4	8.0	-	-	-	-	-	8.0	-	20.4
	Subtotal	226.0	116.4	11.2	13.7	1.0	28.0	-	170.3	23.0	32.7
	Exports	33.3	-	-	30.9	2.4	-	-	33.3		
	Exchanges	-	23.0	-	-	-	-	-	23.0	(23.0)	-
	Total	259.3	139.4	11.2	44.6	3.4	28.0	-	226.6	-	32.7
1990											
	Supply		107.2	8.7	35.8	3.7	36.0	14.3	205.7		
	Allocate										
	British Columbia	25.7	21.0	.4	-	.3	4.0	-	25.7		-
	Prairie Provinces	53.7	31.8	2.3	6.1	1.4	12.1	-	53.7		-
	Ontario	70.1	37.5	4.0	9.7	-	10.9	-	62.1	8.0	-
	Quebec	42.9	3.6	2.0	2.8	-	9.0	7.2	24.4	5.5	13.0
	Atlantic	21.5	-	-	-	-	-	7.1	7.1	-	14.4
	Subtotal	213.9	93.7	8.7	18.6	1.7	36.0	14.3	173.0	13.5	27.4
	Exports	19.2	-	-	17.2	2.0	-	-	19.2		
	Exchanges	-	13.5						13.5	(13.5)	
	Total	233.1	107.2	8.7	35.8	3.7	36.0	14.3	205.7	-	27.4
1995											
	Supply		88.7	8.6	39.0	3.8	36.0	56.0	232.1		
	Allocate										
	British Columbia	26.4	21.9	-	-	.5	4.0	-	26.4		-
	Prairie Provinces	58.2	30.7	1.6	6.5	1.7	17.7	-	58.2		-
	Ontario	67.3	28.1	4.0	10.2	-	14.3	-	56.6	8.0	2.7
	Quebec	38.8	-	-	-	-	-	32.9	32.9	-	5.9
	Atlantic	20.2	-	-	-	-	-	19.1	19.1	-	1.1
	Subtotal	210.9	80.7	5.6	16.7	2.2	36.0	52.0	193.2	8.0	9.7
	Exports	30.9	-	3.0	22.3	1.6	-	4.0	30.9		
	Exchanges	-	8.0						8.0	(8.0)	
	Total	241.8	88.7	8.1	39.0	3.8	36.0	56.0	232.1	-	9.7

Note: (1) Hycarb forecast, "Canadian Refining Outlook to 1992, March, 1983.

TABLE C-3

CRUDE OIL ALLOCATION, 1995 SENSITIVITIES
(Thousands of Cubic Metres Per Calendar Day)

Sensitivity - High Crude Oil Demand

Year	Region	Total Demand	Light	Pentanes Plus	Medium/ Heavy	Bitumen	Synthetic	Frontier	Total Supply	Imported Crude: Via Exchanges	Imported Crude: Purchased Imports
1995											
	Supply		88.7	8.6	39.0	3.8	36.0	56.0	232.1		
	Allocate										
	British Columbia	26.4	21.3	.7	-	.4	4.0	-	26.4		-
	Prairie Provinces	71.8	40.1	3.5	6.5	2.2	19.5	-	71.8		-
	Ontario	78.6	19.3	4.4	10.2	-	12.5	15.0	61.4	8.0	9.2
	Quebec	52.3	-	-	-	-	-	27.5	27.5	-	24.7
	Atlantic	25.9	-	-	-	-	-	13.5	13.5		12.4
	Subtotal	255.0	80.7	8.6	16.7	2.6	36.0	56.0	200.6	8.0	46.3
	Exports	23.5	-	-	22.3	1.2	-	-	23.5		
	Exchanges	-	8.0						8.0	(8.0)	
	Total	278.5	88.7	8.6	39.0	3.8	36.0	56.0	232.1	-	46.3

Sensitivity - High Synthetic Crude Oil Supply

Year	Region	Total Demand	Light	Pentanes Plus	Medium/ Heavy	Bitumen	Synthetic	Frontier	Total Supply	Imported Crude: Via Exchanges	Imported Crude: Purchased Imports
1995											
	Supply		88.7	8.6	39.0	3.8	56.0	56.0	252.1		
	Allocate										
	British Columbia	26.4	18.4	-	-	1.0	7.0	-	26.4		-
	Prairie Provinces	58.2	25.5	1.6	6.5	1.7	22.9	-	58.2		-
	Ontario	67.3	28.0	4.0	10.2	-	17.1	-	59.3	8.0	-
	Quebec	38.8	3.9	2.0	3.0	-	9.0	18.0	35.9	-	2.9
	Atlantic	20.2	-	-	-	-	-	19.1	19.1		1.1
	Subtotal	210.9	75.7	7.6	19.7	2.7	56.0	37.1	198.8	8.0	4.0
	Exports	45.3	5.0	1.0	19.3	1.1	-	18.9	45.3		
	Exchanges	-	8.0						8.0	(8.0)	
	Total	256.1	88.7	8.6	39.0	3.8	56.0	56.0	252.1	-	4.0

HYCAP Engineering Ltd.

APPENDIX "D"

REFINERY CAPACITY

TABLE D-1

1985 REFINERY CAPACITIES - BRITISH COLUMBIA AND TERRITORIES
(Thousands of Cubic Metres Per Calendar Day)

Refinery	Location	Unit Capacity									
		Crude	Vacuum Distillation	Catalytic Cracking	Hydrocracking	Thermal Operations	Catalytic Reforming	Alkylation/ Polymerization[1]	Hydrotreating[2]	Aromatics	Asphalt
Operating											
British Columbia											
Chevron	Burnaby	5.6	1.3	1.5	-	-	1.5	.1[1]	1.5	-	.3
Gulf	Port Moody	5.9	2.3	1.8	-	-	1.6	.2	4.6	-	-
Husky	Prince George	1.5	.6	.4	-	-	.2	-	1.1	-	.2
Imperial	Ioco	6.5	2.6	1.9	-	-	1.0	.2	2.6	.1	-
Petro-Canada	Taylor	2.9	.2	1.0	-	-	.5	.1	1.7	-	.1
Shell	Burnaby	3.5	1.1	0.9	-	-	.4	.1[1]	2.6	-	.4
Northwest Territories											
Imperial	Norman Wells	.5	-	-	-	-	-	-	-	-	-
Total		26.4	8.1	7.9	-	-	5.2	.3 .4[1]	14.1	.1	1.0
Shut Down After 1981											
Gulf	Kamloops	1.5	.5	.4	-	-	.3	-	.9	-	.1

Notes: (1) Polymerization, if noted.
(2) Includes naphtha pretreating for catalytic reforming.

HYCARB ENGINEERING LTD.

TABLE D-2

1985 REFINERY CAPACITIES - PRAIRIE PROVINCES
(Thousands of Cubic Metres Per Calendar Day)

Refinery	Location	Unit Capacity									
		Crude	Vacuum Distillation	Catalytic Cracking	Hydrocracking	Thermal Operations	Catalytic Reforming	Alkylation/ Polymerization(1)	Hydrotreating(2)	Aromatics/ Lubricants(3)	Asphalt
Operating Fuel Refineries											
Saskatchewan Co-Op	Regina	6.8	3.0	2.1	-	1.0(4)	1.5	.2(2)	2.4	-	-
Alberta Gulf	Edmonton	19.5	4.4	4.9	-	1.3(4)	2.2	1.5	11.8	-	-
Imperial	Edmonton	26.3	7.6	8.9	-	-	3.3	2.2	8.1	.5(3)	2.5
Shell	Bruden	.8	-	-	-	-	.4	-	.4	-	-
Shell	Scotford(5)	7.6	-	-	5.2	-	3.1	-	6.0	1.8	-
Turbo	Balzac	4.5	1.0	1.6	-	-	1.2	.4(1)	2.4	-	-
Subtotal		65.5	16.0	17.3	5.2	2.3(4)	11.7	3.7 .6(1)	31.1	1.8 .5(3)	2.5
Asphalt Refineries											
Saskatchewan Gulf	Moose Jaw	2.1	1.2	-	-	-	-	-	-	-	.9
Alberta Husky	Lloydminster	3.7	2.8	-	-	-	-	-	-	-	1.9
Subtotal		5.8	4.0	-	-	-	-	-	-	-	3.6
Total		71.3	20.0	17.3	5.2	2.3(4)	11.7	3.7 .6(1)	31.1	1.8 .5(3)	5.3
Shut Down After 1981											
Fuel Refineries											
Manitoba Shell	St. Boniface	4.8	.9	1.1	.2	-	1.2	.1(1)	1.2	-	.3
Texaco	Edmonton	5.3	1.2	1.2	-	.6(4)	.8	.1(1)	1.2	-	-
Subtotal		10.1	2.1	2.4	.2	.6	2.0	.2	2.4	-	.3
Asphalt Refineries											
Alberta Gulf	Calgary	1.4	.4	-	-	-	-	-	-	-	.8
Total		11.5	2.5	2.4	.2	.6	2.0	.2(1)	2.4	-	1.1

Notes: (1) Polymerization, if noted.
(2) Includes naphtha pretreating for catalytic reforming.
(3) Lubricants, if noted.
(4) Delayed coking.
(5) 1984 startup.

TABLE D-3

1985 REFINERY CAPACITIES - ONTARIO
(Thousands of Cubic Metres Per Calendar Day)

Refinery	Location	Unit Capacity									
		Crude	Vacuum Distillation	Catalytic Cracking	Hydrocracking	Thermal Operations	Catalytic Reforming	Alkylation	Hydrocreating(1)	Aromatics/ Lubricants(2)	Asphalt
Operating											
Fuel Refineries											
Gulf	Clarkson	.8	.8	-	-	-	-	-	-	.8(2)	-
Imperial	Sarnia	20.0	4.5	3.8	1.7	2.1(3)	4.6	.9	14.6	.9(2) .6	-
Petro-Canada	Oakville	12.7	6.5	3.5	-	-	2.6	.7	4.0	-	1.5
Shell	Corunna	11.8	4.1	2.5	1.2	.5(4)	3.7	-	3.8	.5	-
Suncor	Sarnia	10.3(5)	2.4(6)	2.5	3.0(6)	.9(4)	4.9	.6	4.9	1.2	-
Texaco	Nanticoke	15.1	4.7	5.9	-	-	3.6	1.1	3.6	.2(7)	-
Subtotal		70.7	23.0	18.2	5.9	3.5	19.4	3.3	30.9	2.5 1.7(2)	1.5
Chemical Refineries											
Petrosar	Corunna	9.5	5.3	-	-	-	-	-	-	-	-
Total		80.2	28.3	18.2	5.9	3.5	19.4	3.3	30.9	2.5 1.7(2)	1.5
Shutdown After 1981											
Fuel Refineries											
Shell	Oakville	7.0	1.8	2.2	-	-	1.1	.4	4.6	-	-
Gulf(9)	Clarkson	11.8	3.4	2.7	-	-	1.0	.5 .1(8)	4.8	-	.9
Total		18.8	5.2	4.9	-	-	2.1	.9 .1(8)	9.4	-	.9

Notes: (1) Includes naphtha pretreating for catalytic reforming.
(2) Lubricants, if noted.
(3) Fluid coking.
(4) Visbreaking.
(5) Available capacity = 14.3 10^3m^3/cd.
(6) 1984 start-up.
(7) Aromatics at Port Credit.
(8) Polymerization, if noted.
(9) Clarkson refinery to operate as a lube plant, with crude vacuum, and catalytic reforming capacity to serve Montreal East refinery.

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TABLE D-4

1985 REFINERY CAPACITIES - QUEBEC
(Thousands of Cubic Metres Per Calendar Day)

Refinery	Location	Unit Capacity									
		Crude	Vacuum Distillation	Catalytic Cracking	Hydrocracking	Thermal Operations	Catalytic Reforming	Alkylation/ Polymerization(1)	Hydrotreating(2)	Aromatics/ Lubricants(3)	Asphalt
Operating											
Gulf	Montreal East	16.8(4)	7.9(5)	3.3	-	-	2.9(6)	.2(1)	4.1	.5	.8
Petro-Canada	Pointe aux Trembles	14.8	6.8	3.0	2.4	2.1(7)	4.8	.1(1) .2	6.5	1.4	1.5
Shell	Montreal East	19.1	8.3	3.7	2.1	1.4(7)	3.7	.2	10.6	.5(3)	1.3
Ultramar	St. Romuald	12.7(8)	5.0	4.4	-	-	2.2	1.0(1)	3.9	-	1.5
Total		63.4	28.0	14.4	4.5	3.5(7)	13.6	1.3(1) .4	25.1	1.9 0.5(3)	5.1
Shutdown After 1981											
BP(9)	Ville d'Anjou	11.3	3.0	3.0	-	-	1.8	.1(1)	6.5	-	1.7
Imperial	Montreal East	12.6	7.1	3.4	-	-	1.7	.4(1)	7.3	-	-
Texaco	Montreal East	11.8	4.9	4.2	-	1.9(7)	1.9	.2(1) .5	3.8	-	-
Total		35.7	15.0	11.0	-	1.9(7)	5.4	.7(1) .5	17.6	-	1.7

Notes: (1) Polymerization, if noted.
(2) Includes naphtha pretreating for catalytic reforming.
(3) Lubricants, if noted.
(4) Includes 7.2 $10^3m^3/d$ at Clarkson, Ontario.
(5) Includes 3.4 $10^3m^3/d$ at Clarkson, Ontario.
(6) Includes 1.6 $10^3m^3/d$ at Clarkson, Ontario.
(7) Visbreaking
(8) Available capacity = 16.4 $10^3m^3/cd$.
(9) Now Petro-Canada.

HYCARB ENGINEERING LTD.

TABLE D-5

1985 REFINERY CAPACITIES - ATLANTIC PROVINCES
(Thousands of Cubic Metres Per Calendar Day)

Refinery	Location	Unit Capacity									
		Crude	Vacuum Distillation	Catalytic Cracking	Hydrocracking	Thermal Operations	Catalytic Reforming	Polymerization	Hydrotreating[1]	Aromatics/ Lubricants	Asphalt
Operating											
New Brunswick											
Irving	St. John	19.5[2]	9.8	2.8	4.8	4.0[3]	5.7	.3	14.4	-	2.0
Nova Scotia[4]											
Imperial	Dartmouth	13.0	6.3	3.5	-	-	1.3	.4	6.8	-	1.0
Texaco	Halifax	3.2	1.3	1.1	-	-	.5	-	1.3	-	-
Total[5]		35.7	17.4	7.4	4.8	4.0	7.5	.7	22.5	-	3.0
Shutdown After 1981											
Newfoundland											
Ultramar	Holyrood	2.1	-	-	-	-	.2	-	.8	-	-

Notes: (1) Includes naphtha pretreating for catalytic reforming.
(2) Available capacity = 17.8 $10^3 m^3$/cd.
(3) Visbreaker.
(4) Excludes Gulf at Pt. Tupper.
(5) Excludes Petro-Canada at Come-By-Chance.

TABLE D-6

CANADIAN REFINING CAPACITY
(Thousands of Cubic Metres Per Day)

Western Canada			
Refinery	Effective Crude Capacity		
	1981	Change	1985-95
British Columbia & Territories			
Chevron, Burnaby	5.6	-	5.6
Gulf/Petro-Canada, Port Moody	5.9	-	5.9
Gulf, Kamloops	1.5	(1.5)	-
Husky, Prince George	1.5	-	1.5
Imperial, Ioco	6.5	-	6.5
Imperial, Norman Wells	0.5	-	0.5
Petro-Canada, Taylor	2.3	0.6	2.9
Shell, Burnaby	3.5	-	3.5
Subtotal	27.3	(0.9)	26.4
Prairie Provinces			
Co-Op, Regina	6.8	-	6.8
Gulf, Edmonton	12.7	6.8	19.5
Gulf, Calgary	1.4	(1.4)	-
Gulf, Moose Jaw	2.1	-	2.1
Husky, Lloydminster	1.8	1.9	3.7
Imperial, Edmonton	24.0	2.3	26.3
Shell, Bowden	0.8	-	0.8
Shell, Scotford	-	7.6	7.6
Shell, St. Boniface	4.8	(4.8)	-
Texaco, Edmonton	4.5	(4.5)	-
Turbo, Calgary	-	4.5	4.5
Subtotal	58.9	12.4	71.3
TOTAL	86.2	11.5	97.7

Eastern Canada			
Refinery	Effective Crude Capacity		
	1981	Change	1985-95
Ontario			
Gulf, Clarkson	12.6	(11.8)(1)	0.8
Imperial, Sarnia	20.0	-	20.0
Petro-Canada (BP), Oakville	12.7	-	12.7
Petrosar, Corunna	14.3	(4.8)	9.5
Shell, Corunna	11.8	-	11.8
Shell, Oakville	7.0	(7.0)	-
Suncor, Sarnia	14.3	(4.0)	10.3
Texaco, Nanticoke	15.1	-	15.1
Subtotal	107.8	(27.6)	80.2
Quebec			
Gulf, Montreal East	11.8	5.0(1)	16.8
Imperial, Montreal East	12.6	(12.6)	-
Petro-Canada, Pte. aux Trembles	14.8	-	14.8
Petro-Canada (BP), Ville d'Anjou	11.3	(11.3)	-
Shell, Montreal East	19.1	-	19.1
Texaco, Montreal East	11.8	(11.8)	-
Ultramar, St. Romuald	16.4	(3.7)	12.7
Subtotal	97.8	(34.4)	63.4
Atlantic Provinces			
Imperial, Dartmouth	13.0	-	13.0
Irving, St. John	26.7	(7.2)	19.5
Texaco, Halifax	3.2	-	3.2
Ultramar, Holyrood	2.1	(2.1)	-
Subtotal	45.0	(9.3)	35.7
	250.6	(71.3)	179.3
TOTAL CANADA	336.8	(59.8)	277.0

Note: (1) Approximately 7.2 $10^3m^3/d$ crude capacity to operate at Clarkson for Montreal East refinery.

APPENDIX "E"

REFINERY LINEAR PROGRAM

APPENDIX E

Refinery Linear Program

The in-house Hycarb linear program (LP) is a complex material and energy balance and optimization model which is capable of analyzing a variety of refinery related circumstances. If feasibly constrained, the model can assist in establishing the trends in future refinery operations necessary to meet the forecast production requirements. Alternatively, if the forecast production is beyond the capabilities of the refinery configuration, the model will identify supply shortages.

The model treats each regional refining community as one large hypothetical refinery. The model is further constrained to maintain the individual character of specific refineries or any unusual circumstances. In this regard, it is recognized that the community does not behave as one large refinery. For example, petroleum products are not comingled. One refinery may give away product quality in a particular product line, whereas another refiner, because of the refinery configuration and the particular market sector he is serving, may be tight in that particular product quality. To compensate somewhat, the model has been overconstrained to recognize a certain degree of imbalance in the production of refinery products.

The model is comprised of the following components:

- a data bank of detailed crude oil assays representative of all the crudes processed in Canadian refineries,
- a detailed set of refinery operation models, which includes; catalytic cracking, catalytic reforming, hydrocracking, alkylation, visbreaking, aromatics recovery, desulphurization, atmospheric and vacuum distillation, asphalt production, delayed coking, fluidcoking, and light-ends recovery,
- a complete set of petroleum products specifications, and a petroleum products blending logic which allows products streams from the various processing units to be blended in a fashion comparable to that which is actually taking place within the refineries, and
- a set of crude oil prices, petroleum product prices and unit operating costs.

Figure E-1 is a flow diagram of the computer input and output. An overall process flow diagram of a generalized complex refinery is presented in Figure E-2.

Product specifications vary on a regional basis and on end consumer. To facilitate the analysis, some generalizations were necessary. Table E-1 summarizes the product specifications used in this analysis.

The crude oils selected for the LP analyses represent major crude types. Selected properties are summarized in Table E-2. Frontier crude quality is assumed, based on discussions with others and limited data.

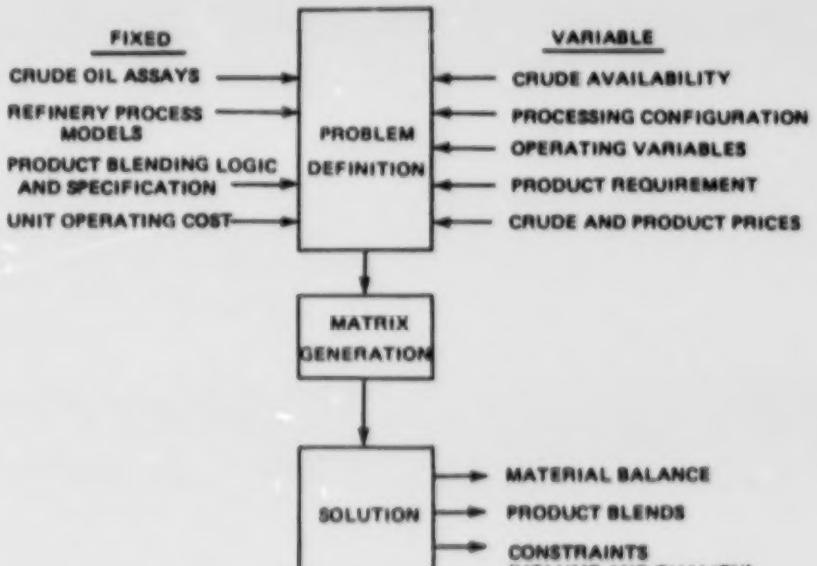

FIGURE E-1 REFINERY LINEAR PROGRAMMING MODEL

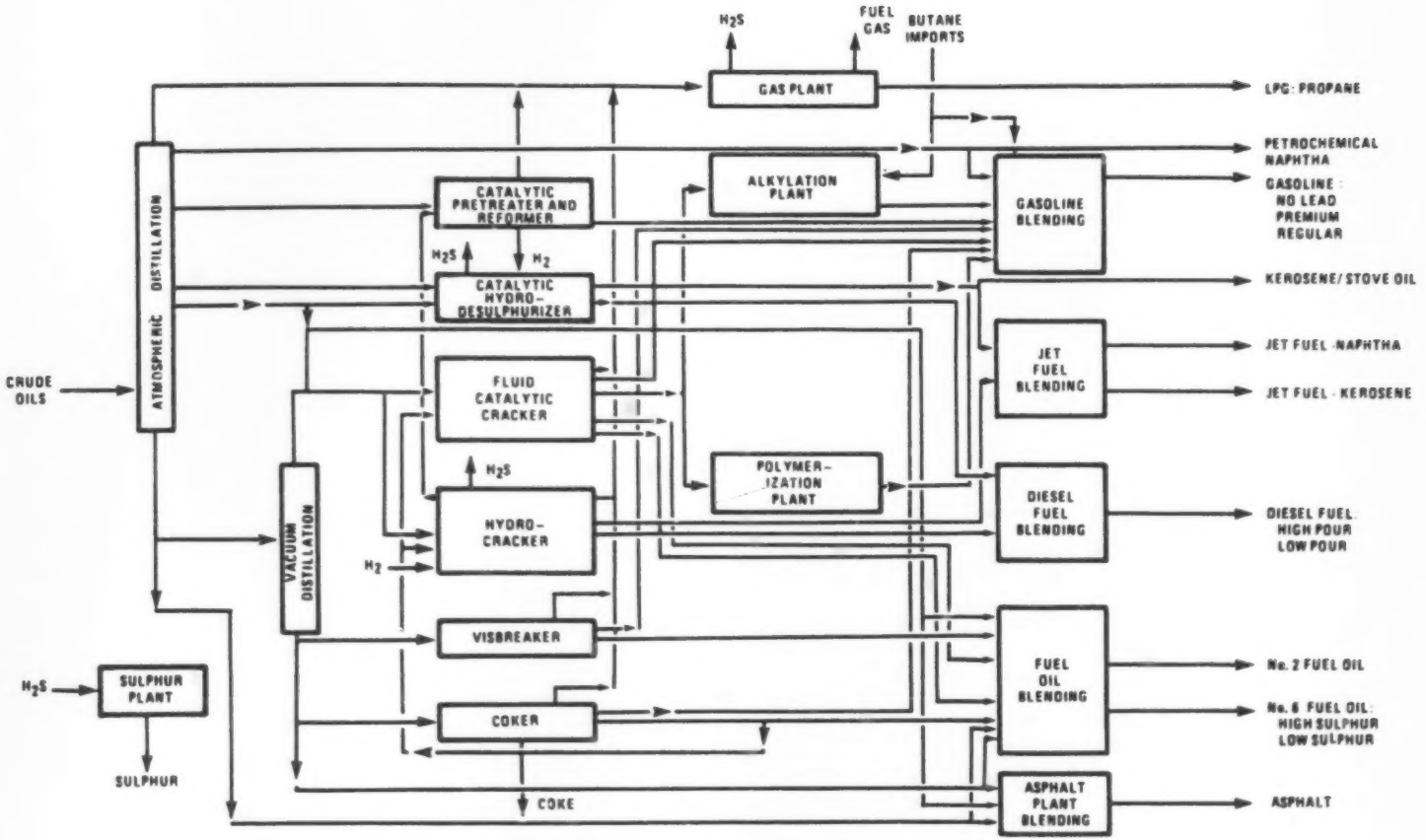

FIGURE E–2 GENERALIZED REFINERY BLOCK FLOW DIAGRAM

TABLE E-1

REFINERY MODEL PRODUCT SPECIFICATIONS(1)

	Jet A	Winter Diesel	Summer Diesel	Stove	LFO	HFO	Motor Gasoline		
							Leaded	Unleaded	
							Regular	Regular	Premium
Maximum Gravity °API	51	-	-	-	-	-	-	-	-
Minimum Gravity °API	39	-	-	-	-	-	-	-	-
Maximum Sulphur Wt.%	0.13	0.5	0.5	0.2	0.5	-(2)	-	-	-
Maximum Viscosity CS 50°C	-	3.5	3.5	3.5	3.5	550	-	-	-
Minimum Viscosity CS 50°C	-	1.60	1.65	-	-	100	-	-	-
Minimum Flash °C	39.4	51.7	51.7	43.3	43.3	65.6	-	-	-
Minimum Cetane Index	-	45.0	45.0	-	-	-	-	-	-
Minimum Smoke Point mm	20	-	-	-	-	-	-	-	-
Maximum Pour Point °C	-	-40.0(3)	-6.7(3)	-40.0	-17.8	-	-	-	-
Maximum Freeze Point °C	-50	-	-	-	-	-	-	-	-
Research Octane Number	-	-	-	-	-	-	94	93	96
Motor Octane Number	-	-	-	-	-	-	85	84	86
% Off @ 70°C	-	-	-	-	-	-	20-40	20-40	20-40
% Off @ 100°C	-	-	-	-	-	-	35-65	35-65	35-65
Maximum g/l	-	-	-	-	-	-	0.44	-	-
RVP psia	-	-	-	-	-	-	11.0	11.0	11.0

Notes: (1) Distillation ranges on middle distillates controlled by limiting blending stocks available to program blending logic.

(2) Varies from 0.7 wt.% to 3.0 wt.%, depending on region and time period.

(3) Actual regional pour point specifications recognized by blending summer and winter grades, except for High Arctic, where Jet A is substituted for diesel.

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TABLE E-2

CRUDE OIL PROPERTIES

	Canadian Crude					Foreign Crude		
	Alberta Mixed Blend(1)	Pentanes Plus	Synthetic	Diluted Lloydminster	Frontier	Arabian Light	Tia Juana Medium	Maya
Bulk Properties								
Gravity, °API	38.0	59.5	32.8	22.1	32.0	33.5	24.5	22.5
Sulphur, wt.% S	.6(1)	.3	.1	3.0	1.0	1.7	1.6	3.4
Distillation, LV %								
C_4 minus	3.4	5.8	2.6	.2	2.6	2.5	1.6	1.3
C_5 - 180°F	8.1	27.2	4.2	2.5	5.9	8.2	3.2	7.2
180-380°F	25.5	43.0	14.1	17.0	19.7	18.9	12.7	14.3
380-650°F	28.0	20.0	45.1	21.5	26.4	27.1	24.3	21.4
650-1050°F	28.0	4.0(2)	34.0	35.5	30.2	29.4	32.9	28.2
1050+°F	7.0	0.0	0.0	23.3	15.2	13.9	25.3	27.6
Selected Component Properties								
C_5-180°F								
RON-C1	72.6	72.6	62.0	64.8	71.9	56.5	71.0	67.0
180-380°F								
N + 2A, LV %(3)	64.5	64.5	86.0	50.0	67.2	40.0	70.4	36.0
380-550°F								
Smoke Pt., mm	24.0	24.0	13.0	25.0	22.2	23.0	20.0	23.0
450-650°F								
Cetane Index	51.6	51.6	36.0	41.0	51.3	58.0	51.0	48.8
Pour Point, °F	0.0	4.0	-35.0	-18.0	-5.0	-5.0	-12.0	5.0
Sulphur, wt.% S	.2	.2	< .1	1.5	.4	1.1	.7	1.5
650-1050°F								
Characterization, K	11.9	11.8	11.5	11.2	11.7	11.7	11.5	11.7
Sulphur, wt.% S	.8(1)	.4	.2	3.0	1.1	2.1	1.8	2.8
1050+°F								
Sulphur wt.% S	1.5	-	-	8.0	2.4	4.0	3.5	4.5

Notes: (1) Sweet crude available, wt.% S = 0.4 for crude, 0.5 for (650-1050 °F), and 1.0 for (1050+ °F).
(2) 650-750°F.
(3) Naphthenes + 2(Aromatics).

APPENDIX "F"

CRUDE/PRODUCT PRICING

TABLE F-1

PRODUCT PRICING - BRITISH COLUMBIA AND TERRITORIES

	1981	1982	1985	1990	1995
Crude Cost, $/m^3	172.94	209.24	229.27	311.29	412.33
Gross Margin, $/m^3	41.10	43.16	43.84	56.39	74.66
Average Sales Realization, $/m^3	210.82	247.35	267.65	360.33	477.25
Realization Ratios					
Gasoline	1.10	1.11	1.10	1.085	1.085
Jet Fuel	1.07	1.09	1.08	1.08	1.08
Diesel	1.06	1.00	1.06	1.06	1.065
LFO	1.02	1.00	.97	.96	.96
HFO (1.5 wt.% S)	.64	.64	.71	.67	.67
HFO (3.0 wt.% S)	.61	.63	.69	.64	.64
Other	.75	.77	.85	.85	.86

T A B L E F-2

PRODUCT PRICING - PRAIRIE PROVINCES

	1981	1982	1985	1990	1995
Crude Cost, $/m^3	168.32	203.99	222.04	302.32	401.53
Gross Margin, $/m^3	35.44	43.55	45.08	56.52	70.50
Average Sales Realization, $/m^3	198.09	239.12	258.71	341.51	457.39
Realization Ratios					
Gasoline	1.09	1.10	1.08	1.07	1.06
Jet Fuel	1.11	1.09	1.07	1.07	1.065
Diesel	1.08	1.01	1.04	1.05	1.055
LFO	1.04	.97	.96	.96	.96
HFO	.64	.60	.60	.61	.61
Other	.66	.60	.75	.76	.77

TABLE F-3

PRODUCT PRICING - ONTARIO

	1981	1982	1985	1990	1995
Crude Cost, $/m^3	173.38	209.97	229.76	311.61	408.86
Gross Margin, $/m^3	29.32	29.76	41.96	55.65	75.48
Average Sales Realization, $/m^3	201.44	238.30	270.09	365.05	481.43
Realization Ratios					
Gasoline	1.12	1.12	1.07	1.07	1.05
Jet Fuel	1.06	1.04	1.05	1.05	1.04
Diesel	1.03	1.02	1.03	1.03	1.02
LFO	.99	.98	.96	.96	.96
HFO (1.5 wt.% S)	.72	.67	.66	.66	.66
HFO (3.0 wt.% S)	.69	.64	.68	.63	.63
Other	.99	1.00	.98	.99	.99

TABLE F-4

PRODUCT PRICING - QUEBEC
(Dollars Per Cubic Metre Unless Noted)

	1981	1982	1985	1990	1995
Crude Cost, $/m^3	174.83	208.84	229.37	309.49	406.08
Gross Margin, $/m^3	27.03	22.22	37.81	48.35	58.23
Average Sales Realization, $/m^3	197.96	229.67	265.58	355.69	461.53
Realization Ratios					
Gasoline	1.18	1.21	1.12	1.14	1.15
Jet Fuel	1.11	1.07	1.06	1.09	1.09
Diesel	1.09	1.05	1.03	1.06	1.07
LFO	1.04	1.00	.98	.96	.96
HFO (1.5% S)	.73	.74	.67	.66	.67
HFO (3.0% S)	.67	.66	.69	.64	.64
Other	.93	.93	.98	.99	1.01

TABLE F-5

PRODUCT PRICING - ATLANTIC PROVINCES

	1981	1982	1985	1990	1995
Crude Cost, $/m^3	173.29	205.33	222.51	301.61	404.23
Gross Margin, $/m^3	36.98	41.80	34.24	50.14	69.54
Average Sales Realization. $/m^3	200.95	240.21	249.56	341.90	460.50
Realization Ratios					
Gasoline	1.18	1.13	1.12	1.17	1.15
Jet Fuel	1.17	1.07	1.10	1.15	1.11
Diesel	1.16	1.05	1.06	1.13	1.09
LFO	1.06	1.03	1.02	1.00	.96
HFO	.70	.80	.79	.65	.65
Other	.76	.77	.82	.79	.79

TABLE F-6

FUEL OIL PRICES
(Dollars Per Cubic Metre)

	1981	1982	1985	1990	1995
British Columbia and Territories					
Diesel Fuel - Winter	225.97	249.07	286.55	385.77	513.35
- Summer	221.49	247.00	280.87	378.13	503.19
LFO	214.79	247.40	259.62	345.92	458.16
HFO (3.0% S)	128.31	155.11	183.42	230.35	305.12
Prairie Provinces					
Diesel Fuel - Winter	216.18	244.09	272.28	369.40	488.34
- Summer	210.83	238.31	265.82	360.64	476.76
LFO	205.49	232.43	248.36	333.74	439.10
HFO	126.24	142.79	155.43	211.63	281.07
Ontario					
Diesel Fuel - Winter	209.15	246.12	281.53	380.52	496.95
- Summer	203.97	240.28	274.85	371.50	485.17
LFO	199.70	232.82	259.29	350.45	462.18
HFO (3.0% S)	139.04	152.31	177.14	230.59	302.56
Quebec					
Diesel Fuel - Winter	217.28	243.85	277.64	382.69	501.24
- Summer	212.39	236.65	269.44	371.37	486.42
LFO	206.28	230.74	260.26	341.46	443.07
HFO (3.0% S)	132.45	152.13	176.84	229.02	300.50
Atlantic Provinces					
Diesel Fuel - Winter	235.41	254.20	267.70	390.99	507.97
- Summer	229.58	248.18	261.36	381.71	495.93
LFO	213.33	247.82	254.55	341.90	442.08
HFO	141.13	191.51	198.03	223.19	299.13

HH

TP 5100

FUELS FOR RAILWAY AND MARINE DIESELS - SUMMARY REPORT

Prepared for the

TRANSPORTATION DEVELOPMENT CENTRE

Prepared by

Hycarb Engineering Ltd.

December, 1983

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FUELS FOR RAILWAY AND MARINE DIESELS -

SUMMARY REPORT

by

Hycarb Engineering Ltd.

T. H. Wise
G. R. Crandall
J. N. Zanyk

December, 1983

HYCARB ENGINEERING LTD.

The contents of this report reflect the views of the contractor and not necessarily the official views or policies of the Transport Canada, Transportation Development Centre.

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17. Abstract

An investigation was undertaken to determine the future availability and quality of fuels for railway and marine diesels. In this regard, a forecast of petroleum product demand crude oil availability up to 1995 was established. The petroleum refining industry was then analyzed as to its ability to adjust operations to meet the future demands. As an aid in the refinery analysis, a linear programming model was utilized to simulate the refining industry on a regional basis. Conclusions with respect to the future supply situation were drawn. Future fuel prices were estimated. Considerations were identified to match engine fuel requirements with fuel quality, to improve fuel quality control, and to reduce fuel costs.

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17. Résumé

Une enquête a été entreprise afin d'évaluer la disponibilité future et la qualité du combustible diesel pour locomotives et navires. A cet effet, on a établi une prévision de la demande de produits pétroliers et de la disponibilité d'huile brute jusqu'en 1995. L'industrie de raffinage du pétrole a subi une analyse permettant d'évaluer sa capacité d'ajuster ses opérations pour répondre aux demandes futures. Afin de faciliter cette analyse, on a utilisé un modèle de programmation linéaire qui représente l'industrie de raffinage sur une base régionale. Ensuite, on a tiré des conclusions sur la situation d'approvisionnements futurs et estimé les prix futurs en carburant diesel. On a identifié les considérations pour mettre en correspondance la demande des moteurs en carburant avec la qualité de ce dernier, améliorer le contrôle de la qualité et réduire le coût de carburant.

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Mr. R. Bertrand	Transportation Development Centre
Mr. D. S. Black	Energy, Mines and Resources
Mr. P. J. Detmold	Railway Advisory Committee
Mr. I. F. Gilbert	Transport Canada
Mr. R. G. Grimsey	National Defence
Mr. D. R. Jackson	CN Rail
Mr. R. G. Maughan	Transportation Development Centre (Consultant)
Mr. D. O. Mullins	CP Rail
Mr. R. S. Nishizaki	Transportation Development Centre
Mr. G. Taylor	Energy, Mines and Resources
Mr. R. B. Whyte	National Research Council
Mr. D. Williams	CN Marine

FOREWORD

The Transportation Development Centre (TDC) of Transport Canada is concerned with availability and quality of fuels for transportation use to ensure that refinery products and engine requirements are compatible and cost effective in the future. Because of substantial changes in the refining industry, TDC retained Hycarb Engineering Ltd. (Hycarb) to study the availability and quality of fuels for both railway and marine diesel applications in Canada. The fuel types include middle distillate and residual products with current or modified specifications (if necessary) from petroleum refineries.

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1. INTRODUCTION

The Canadian petroleum refining industry has been facing and continues to face significant changes in product demand, crude oil supply and processing capabilities. This study examines the capability of the Canadian refining industry in five regions to supply required volumes and quality of all refined products, particularly fuels for railway and marine diesel operators through to 1995. Hycarb used its in-house refinery linear program (LP) for this evaluation. It also examines commercial implications, such as product pricing, as well as possible research and development (R&D) options. This summary report describes the basis, refining analyses, product prices, and diesel engine fuel considerations, followed by Conclusions and Recommendations.

2. PRODUCT DEMAND

The product slate was adapted from the Hycarb study, "Canadian Refining Outlook to 1992". In that study, a "low demand" forecast was developed for each product in each refining region. In general, this was based on the low product demand experienced in 1982, and the low demand growth rates from the National Energy Board (NEB) report of June, 1981, "Canadian Energy, Supply/Demand: 1980-2000". Adjustments were made to reflect more recent changes, such as the effect of delays in installation of natural gas distribution facilities in eastern Canada and their effect on fuel oil demand.

A high demand sensitivity case was examined for 1995 in case of high economic recovery to determine whether the current refinery closures would constrain supply below demand. The high demand forecast is generally based on actual 1981 product demand and forecast middle demand growth rates from the above NEB reports.

The refined product demand forecast is summarized in Figure 1. In the base case forecast, overall product demand is expected to decline by 10% from 1982 to 1995. A large decline (23%) in eastern Canada (Ontario and east) should be partly offset by some increase (19%) in western Canada.

These forecasts are characterized by a decrease in gasoline, light fuel oil (LFO) and heavy fuel oil (HFO) demand, but an increase in jet fuel and diesel fuel demand. Diesel fuel growth is expected primarily for road transport, with moderate growth in other sectors including railway and marine use.

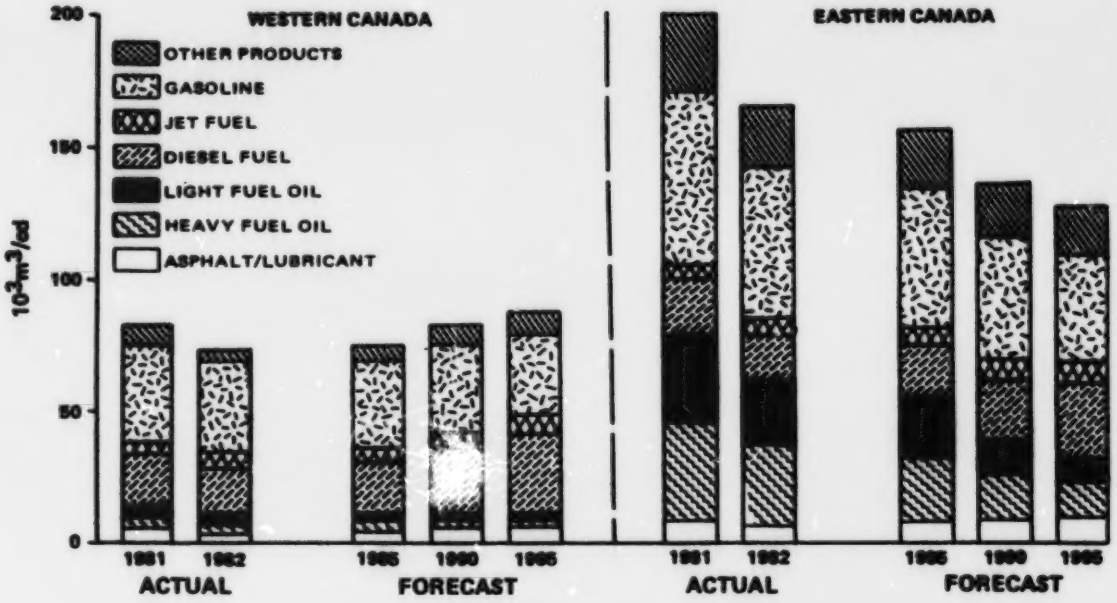

FIGURE 1 REFINED PRODUCT DEMAND (1)

NOTE: (1) INCLUDES REFINERY CONSUMPTION, EXPORTS AND INTER – REGIONAL TRANSFERS

3. CRUDE OIL

The supply of Canadian crude oil was also forecast in the Hycarb multiclient study. This is generally based on the 1981 NEB report, as well as Alberta Energy Resources Conservation Board (ERCB) and Saskatchewan Ministry of Energy and Mines publications. It includes some modifications to reflect cancellation of tar sands projects, and delays in Canadian offshore production. A sensitivity case was examined for 1995, when the possibility of additional synthetic crude production exists.

The supply of Canadian crude oil is characterized as follows: a decline in conventional western light crude oil from 150 thousand cubic metres per calendar day ($10^3m^3/cd$) in 1982 to 89 $10^3m^3/cd$ in 1995, an increase of 8 $10^3m^3/cd$ synthetic crude by 1990, an increase of 13 $10^3m^3/cd$ of heavy crude by 1985, and eastcoast offshore crude coming onstream around 1990, increasing to 56 $10^3m^3/cd$ by 1995.

Crude demand for each region is based on product demand and refining capacity. The Canadian crude supply/demand balance is summarized in Figure 2. Much of the Canadian heavy crude is assumed to be exported, since Canadian refineries cannot handle the volume. Imported crude has been used in Quebec and the Atlantic to balance crude demand with demand. After 1990, eastcoast crude will contribute significantly. By 1995, there

will not likely be enough western crude for Ontario and the west, so eastward flow through the Sarnia-Montreal pipeline will terminate.

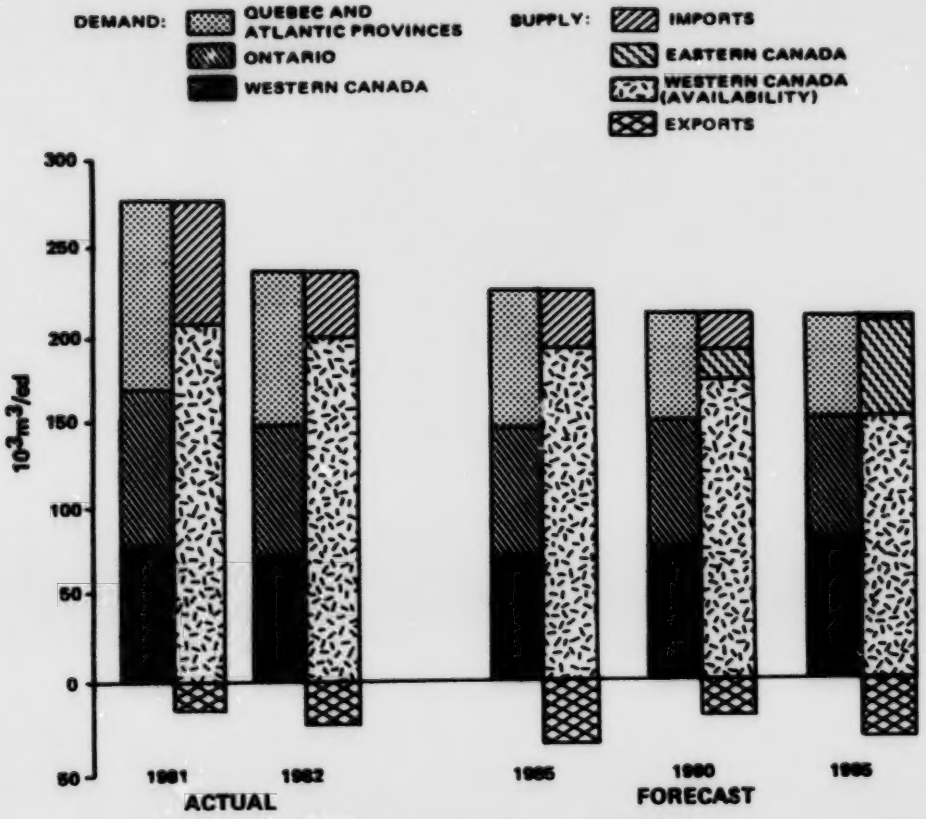

FIGURE 2 CRUDE SUPPLY / DEMAND

4. REFINERY CAPACITY

Refinery capacity has been changing significantly in the past few years. In western Canada, expansions and two grass roots refineries committed around 1980 are still coming on stream. However, product demand has fallen dramatically since 1980, causing considerable overcapacity and the need for rationalization. Between 1981 and 1984, nine refineries will have shut down, representing 57 $10^3m^3/cd$, mostly in Quebec. Including other reductions and expansions, total crude capacity will have decreased from 337 to 277 $10^3m^3/cd$. Refinery crude capacity and throughput is summarized in Figure 3.

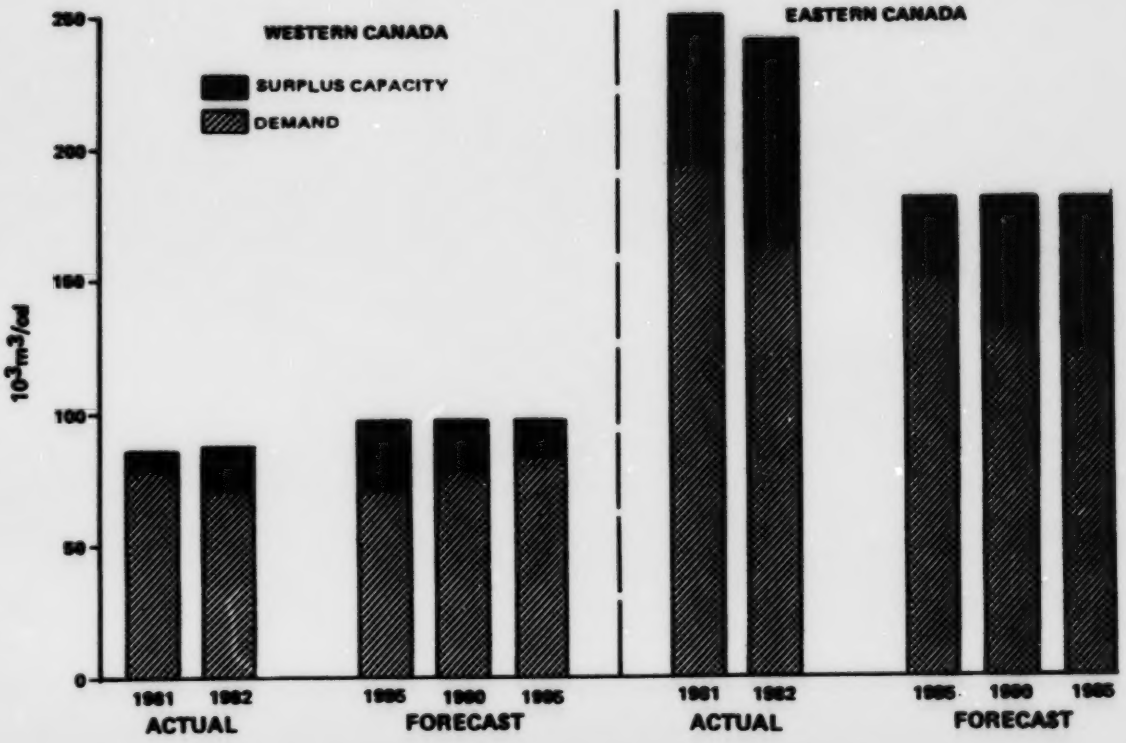

FIGURE 3 REFINERY CRUDE DEMAND/CAPACITY

5. REFINERY ANALYSIS

Hycarb used its in-house refinery LP to model five refining regions (British Columbia and Territories, Prairie Provinces, Ontario, Quebec and Atlantic Provinces) for the years 1981, 1985, 1990, and 1995. Analyses were based on the product slate and crude slates discussed earlier, as well as total unit capacity for each refinery process. The 1995 analyses included sensitivity cases for high demand and for high synthetic crude supply.

In western Canada, the refining industry should have the capability to produce all of the required products, including railway and marine fuels throughout the forecast period. By 1995, the gasoline/distillate ratio will have dropped to .79 (from 1.25 in 1981) resulting in a product imbalance. To produce the required volumes of distillate, additional naphtha or gasoline may be produced for use in eastern Canada.

In eastern Canada, the refining industry should be capable of producing all required products. Although the gasoline/distillate ratio will have fallen from 1.09 to .92 by 1995, this change should not cause an imbalance such as that expected in western Canada. Refineries should have the technical capability to hold HFO production within demand in the

mid-1980's, particularly in Quebec. In the 1990's, an HFO surplus could develop, particularly in Ontario (up to 2.5 $10^3 m^3/d$).

Across Canada, and until at least 1995, the refining industry should be able to supply diesel fuel for railway, marine and other uses, while producing required volumes of all other refined products as well. There may be individual refineries which encounter specific limitations. Seasonal variations in product demand may cause or aggravate product imbalances so that more seasonal storage would be required.

6. FUEL OIL PRICES

A crude and refined product price forecast was developed. Relative pricing of various fuel oils with crude oil is summarized in Table 1. LFO which can be used by railways and probably by many marine diesels is expected to become 10-15% less expensive than diesel fuel. HFO, suitable for many low speed marine diesels, is least expensive. There are large potential fuel savings available for using HFO blends instead of distillates where feasible.

TABLE 1 FUEL OIL PRICING
(Percent of Crude Oil Price, Volume Basis)

	1982	1995
Diesel Fuel (Winter Grade)	117-124	120-126
LFO	110-121	110-115
HFO	73-92	74-80
Blends		
10% HFO/90% LFO	106-118	106-112
30% HFO/70% LFO	99-112	99-105

7. DIESEL ENGINE FUELS

Most diesel engine fuel is a premium distillate fuel, and for most uses refiners produce a single quality product, as specified by cetane number, pour point, cloud point, flash point, sulphur content, viscosity, distillation, and others. Cetane number is usually greater than 40, as required for road diesels. Pour point and cloud point depend on location and climate.

Railways have now relaxed specifications on cetane, pour point and distillation so that typical LFO can satisfy their needs; medium speed railway diesels can burn fuel with a cetane number as low as 30. Marine diesels require fuels ranging in quality from "gas oil" (conventional road diesel) to residual bunker fuel which is specified mainly by viscosity.

7.1 Distillate Fuel

The forecast for distillate demand in Canada is shown in Figure 4. The railway and marine diesels are expected to grow moderately, partly offsetting the decline in LFO demand.

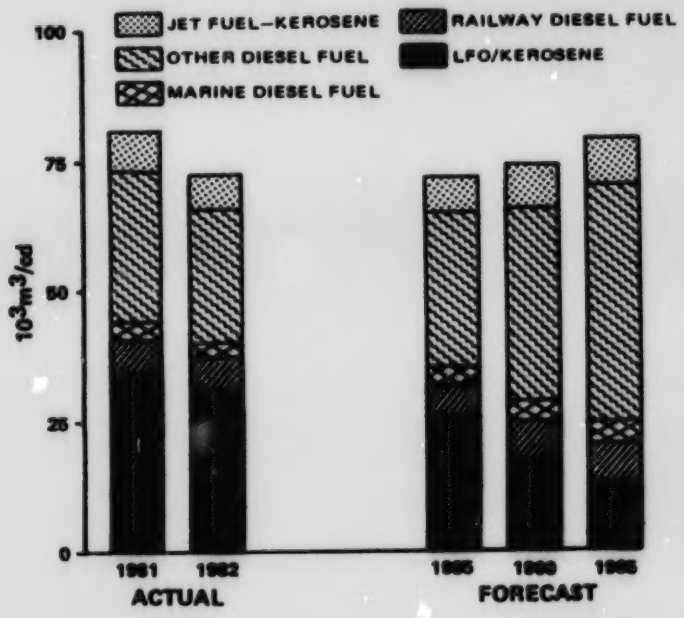

FIGURE 4 MIDDLE DISTILLATE DEMAND IN CANADA

In many regions of Canada, cetane number has not been a problem, as good quality crudes have been available, and low cetane stocks such as fluid catalytic cracker (FCC) cycle oil has been blended into LFO. As the LFO market declines, more of these stocks will be blended into diesel fuel and the cetane number will approach specifications and actual engine requirements more closely. Quality control will become more important. The effectiveness of cetane number (applicability and accuracy) as a measure of diesel fuel quality is under review. Resolution will become more critical.

Although this study has shown that the overall refining industry should be able to meet diesel fuel needs, some individual refineries may have difficulties depending on processing constraints and specific product slates, particularly coping with seasonal variations. Thus, any relaxation in specifications may be advantageous to both consumers and refiners. Relaxation in railway fuel specifications has provided fuel savings to railways while providing an outlet for LFO production by some refiners. Mariners who operate medium speed diesel engines using distillate fuel may have similar opportunities to use LFO quality fuel with resulting savings.

Other quality changes such as higher end points could theoretically allow higher diesel fuel yield, but refinery process changes, as well as isolated storage, handling, and distribution systems, could then be required.

7.2 Heavy Fuel Oil

The forecast for HFO demand in Canada is given in Figure 5. Marine bunker will become a more significant proportion of HFO as industrial demand declines. Although not included in this demand forecast, HFO may be used in fuel blends by railways in the future; commerical tests are underway.

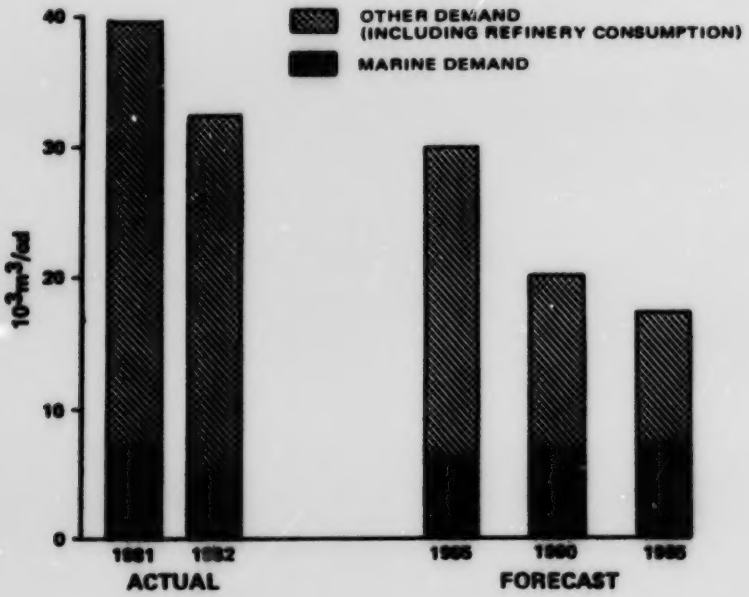

FIGURE 5 HFO DEMAND IN CANADA

The quality of HFO is expected to deteriorate as HFO production decreases, and if crude quality deteriorates. Contaminants such as metals (Vanadium), sulphur, asphaltenes and catalyst fines concentrate in HFO. Engines using HFO, even in blends, could encounter increased operating and maintenance problems unless design improvements are made.

Operators of marine engines using bunker may have potential fuel savings available by increasing maximum viscosity limits (if feasible) and thus reducing cutter stock requirements.

Most marine bunker consumers do not have fuel specifications other than viscosity. To analyse HFO for many other properties which may become more significant (e.g. contaminant concentration), simple procedures are

not available. Marine fuel specifications are being developed by the Canadian Government Specifications Board (CGSB) and the International Standards Association (ISO), but Canadian commercial marine operators are not participating in this process. Marine operators may face increased operating and maintenance problems without engine modifications or refinery production changes (e.g. isolation of HFO containing catalyst fines for boiler or industrial use). As quality deteriorates, quality control needs will increase.

8. CONCLUSIONS

From this analysis, a number of conclusions can be made. Many of them have direct implications to railway and marine fuel users.

1. Diesel fuel demand is expected to increase in all regions of the country throughout the forecast period to 1995. HFO demand will decline except for use as marine bunker fuel.

2. Although refineries have been closing down in recent years because of a decline in sales, there will be sufficient capacity available to produce all of the refined products which will be needed.

3. Marine bunker could be in tight supply until 1990. However, refiners should have the capability to maintain HFO supply within demand.

4. The overall refining industry in each region of Canada should be capable of producing all of the anticipated diesel fuel and marine fuel requirements with current specifications although some regional imbalances may occur. Some individual refineries may have difficulty meeting diesel demand, particularly in winter when gasoline demand is low.

5. As demand for LFO decreases, the actual cetane number of diesel fuel will fall and more closely approach minimum specifications. Given a strong demand for diesel fuel, specific refineries could have difficulty satisfying product demand at current specifications because of processing or market constraints. Transport fuel users who can tolerate lower specification fuels can alleviate potential supply problems.

6. The suitability of cetane number for measuring diesel fuel quality and the use of this test procedure for quality control are questionable. A more precise means of establishing quality of diesel fuels could become essential in order to provide confidence that the fuels will satisfy engine requirements. Current development in this area should be continued.

7. Diesel fuel prices vary seasonally because of quality, but are expected to be 20-25% over crude oil. LFO prices are expected to

be 10-15% above crude oil. HFO prices are expected to be 74-80% of crude oil, except in the Atlantic region where they could remain at more than 90% of crude oil until natural gas becomes available.

8. Railways are investigating the use of blends of 10% HFO with diesel fuel. Special systems may be required by refiners or the railway operators themselves to handle this new product. Although any such changes represent additional costs, fuel savings could still be 3-4% of the cost of diesel fuel. Additional maintenance costs may be incurred.

   In the Prairie region, a 10% HFO blend for railway fuel could increase the HFO market by almost 50%.

9. Although the railway industry has taken steps to use lower cetane fuel commercially, marine operators using diesel fuel or gas oil in medium speed engines have not taken similar steps. This represents an opportunity for them to reduce fuel costs.

10. Some marine operators which are now using diesel fuel in medium speed engines may have an opportunity to reduce costs by receiving a bunker blend of 10% HFO or higher using existing dock-side bunker blending facilties.

11. Because of the temperate environment, coastal marine operators have an opportunity in the winter to accept diesel fuel with higher pour point than land users. This outlet may become more important for refineries as the total demand for diesel fuel increases in these regions. It may also provide a small saving to marine operators.

12. Commercial mariners have not participated directly in establishing marine fuel standards. They are not represented on the CGSB or ISO, both of which are currently involved in developing new marine fuel standards.

13. Marine operators have had operating problems due to contaminants and incompatibility of fuels. Most marine operators do not have fuel specifications, and so cannot control fuel quality. On the other hand, stringent specifications imposed on refiners may require additional handling or even processing steps which could result in additional costs.

14. There are currently not any simple and rapid analytical procedures available for all the marine fuel properties of interest. Some samples are now air freighted to Europe for results within days. Mariners need to ensure satisfactory fuel quality before they leave port.

15. In eastern Canada (Ontario, Quebec, and the Atlantic Provinces), marine bunker fuel will represent an increasing proportion of HFO production throughout the forecast, reaching 30-40% of HFO production by 1995, instead of 7-17% at present. Marine operators could have a stronger position in determining bunker prices and specifications.

16. The quality of HFO available is expected to gradually deteriorate over the next 10-15 years as total HFO production falls, and contaminants concentrate. These contaminants include catalyst fines, metals (e.g. vanadium), and asphaltenes. These could increase operating and maintenance problems for transport users of HFO.

9. RECOMMENDATIONS

Based on the analyses undertaken in this assignment, Hycarb believes the following recommendations are important to railway and marine fuel users:

1. Operators, refiners, and engine manufacturers should seek to match fuel quality and engine requirements, and use lower quality fuels where possible. One excellent example is the use of conventional furnace fuel in railway locomotives.

2. Marine operators should investigate the opportunity for the use of commercially available furnace fuel in medium speed engines. They should also investigate possible fuel changes, such as using high pour point fuels year round, and higher boiling point fuels.

3. Railway operators should continue the laboratory and commercial tests on diesel/bunker blends. However, they should also investigate the systems which are available and/or required to provide this fuel commercially, the maintenance requirements, and establish appropriate cost/benefit relationships.

4. Railways should investigate means of increasing use of heavy fuel by utilizing dual fuel systems, with the lighter fuel used under idling conditions, and a HFO blend under load conditions. Improved preheat, and engine materials should also be considered. Alternatively, auxilliary heating systems could be utilized to avoid idling, and conserve fuel.

5. Marine operators of medium/low speed diesel engines should investigate the use of the heavier fuels because of potential cost savings on cutter stock. This should recognize the fuel needs of auxilliary engines as well as main drives.

6. Marine operators should become more actively involved in determining reasonable fuel specifications in order to protect their equipment in the future. They should participate in committees such as CGSB and ISO.

7. Marine operators should investigate with refiners means of minimizing contaminants in bunker fuel, e.g. isolation of cracker and visbreaker bottoms streams within refineries to use in refinery heaters, or sell as industrial fuels rather than diesel engine fuel. Also, engine manufacturers should investigate improved filtration systems and/or injector systems to tolerate catalyst fines.

8. Contaminant levels in HFO could increase because of increased use of heavy crudes in refineries. For example, vanadium in HFO could increase in Quebec and the Atlantic Provinces because of Mexican or Venezuelan crudes refined there. Engine manufacturers should further investigate improved design or metallurgy to tolerate such impurities.

9. Marine operators should also investigate procedures to improve quality control, such as sampling in advance of receipt and to carry out adequate analyses in time to ensure satisfactory fuel quality before leaving port. Preferrably, some tests should be simple, inexpensive, and carried out onboard. Since many tests involve sophisticated and expensive equipment, consideration should be given to a test laboratory in Canada to serve local needs in minimum time. Alternatively, refiners could be requested to perform the necessary tests.

10. The ongoing review of the applicability of ASTM D613 cetane engine test should be continued in light of various types of diesel fuels, including cracked stocks, and in light of the need for tight quality control in the future. The suitability of alternative ignition quality and/or combustion quality test procedures may have to be investigated further.